COVER SHEET

FEDERAL ENERGY REGULATORY COMMISSION

DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE KLAMATH HYDROELECTRIC PROJECT
Docket No. P-2082-027

Section 3
Environmental Consequences
Pages 3-1 to 3-192
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3.0 ENVIRONMENTAL CONSEQUENCES

In this section, we first describe the general environmental setting in the project vicinity and any environmental resources that could be cumulatively affected by relicensing the Klamath Hydroelectric Project facilities. Then we address each affected environmental resource. For each resource, we first describe the affected environment—the existing condition, and the baseline against which to measure the effects of the proposed project and any alternative actions—and then the environmental effects of the proposed project, including proposed enhancement measures. Unless otherwise stated, the source of our information is the license application for the project (PacifiCorp, 2004a).

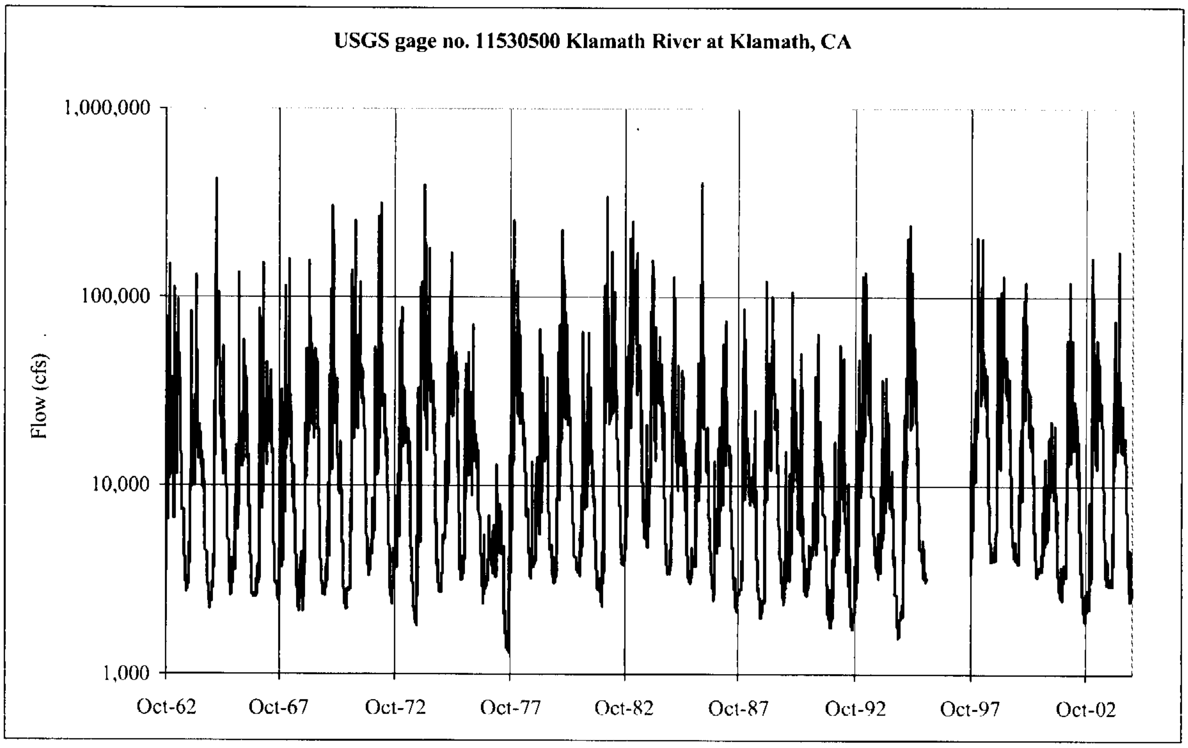
3.1 GENERAL DESCRIPTION OF THE KLAMATH RIVER BASIN

The Klamath River watershed begins in the northwestern-most extent of the Basin and Range physiographic province and is one of only three drainages originating in Oregon that cut across both the Cascade and Coastal ranges. It is also unique because of its large, north-south-striking headwater lake and wetland complex—the Klamath River Basin—located in south-central Oregon and northwestern California. The Klamath River Basin lies in the transition zone between the Modoc Plateau and Cascade Range physiographic provinces, with the Klamath River cutting west through the Klamath Mountain province and then the Coast Range province where it reaches the Pacific Ocean near Requa, California. The Klamath River passes through four distinct geologic provinces, each of which changes the character of the river's channel morphology and that of its tributary watersheds, varying the supply of inputs such as water, sediment, nutrients, and wood.

The upper Klamath Basin, within the Modoc Plateau province, is bounded on its west side by the eastern edge of the Cascades Range, with tributaries of Wood River draining the flanks of the Crater Lake area (see figure 1-1). To the east, the northwesterly trending fault-block mountains with intervening valleys are commonly interspersed with lakebed deposits, shield volcanoes, cinder cones, or lava flows. Shallow lakes (Upper Klamath, Lower Klamath, and Tule lakes) and marshes (Klamath Marsh) are prominent features of the Modoc Plateau, as are areas drained by Anglo-American immigrants. The land surrounding the lakes and the drained lake areas now serves as productive agricultural land. The high-elevation, semi-arid desert environment of the Modoc Plateau receives an average of about 15 inches of precipitation annually. With its porous volcanic geology and relatively moderate topography, runoff is slow, and there are relatively few streams compared to downstream provinces. Sediment yield also is low relative to provinces downstream.

The transition from the Modoc Plateau to the Cascade Range province is subtle; the Klamath River enters the Cascade Range province roughly in the area below Keno dam. The Shasta River is the major tributary to the Klamath River within the Cascade Range province (see figure 1-1). The headwaters of the Shasta River originate on the flanks of Mt. Shasta and the majority of its watershed is comprised of the expansive Shasta Valley (Crandell, 1989). The western side of the Shasta River and Cottonwood Creek watersheds marks the western boundary of this province. The portion of the Cascade Range province included in the Klamath River watershed is largely in the rain shadow of Mt. Shasta and the Klamath Mountains; precipitation is highly variable by elevation and location. Mass wasting and fluvial erosion are the main erosional processes within this province (Forest Service, 2005).

The Klamath Mountains province includes a complex of mountain ranges in southwest Oregon and northwest California, collectively called the Klamath Mountains; they include the Trinity Alps, Salmon Mountains, Marble Mountains, and Siskiyou Mountains. Large tributary watersheds to the Klamath River in this province include the Scott, Salmon, and Trinity rivers. Compared to all other areas of the Klamath River watershed, this province includes some of the steepest topography and tallest mountains; summits in the Trinity Alps exceed 9,000 feet in elevation. Gold-bearing deposits occur within this province, and the legacy effects of gold mining and dredging persist in some areas. Precipitation generally increases in proximity to the coast, so here soils are generally deeper than in



Note: Data for this gage during the 1963–2004 water year period do not include daily flow data for December 31, 1994 to January 6, 1995 and October 30, 1995 to September 30, 1997.

Figure 3-21. Daily flow at USGS gage no. 11530500 Klamath River at Klamath, CA for water years 1963 to 2004. (Source: USGS, 2006, as modified by staff)

3.3.2.1.2 Water Quality

The Klamath River watershed extends from southeastern Oregon to the coast of northern California. Water quality standards (referred to as objectives in California) are set by the Oregon Department of Environmental Quality (Oregon Environmental Quality) and NCRWQCB and published in the Oregon Administrative Rules (OAR) (Oregon Environmental Quality, 2003) and RWQCB Basin Plan (Basin Plan), respectively. According to Oregon Environmental Quality (2003), the existing beneficial uses within the Klamath River to the California border include: municipal and domestic supply, irrigation, stock watering, fish and aquatic life,[35] wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality, hydropower, and commercial navigation and transportation.

[35]Cool water species (no salmonid use) in the Klamath River from Upper Klamath Lake to Keno dam and redband trout from Keno dam to the California border.

According to the Basin Plan, which lists beneficial uses by hydrological area,[36] the existing and potential beneficial uses within the middle and lower Klamath River from the Oregon border to the Pacific Ocean include: municipal and domestic supply, agricultural supply, industrial service and process supply (excluding the Lower Klamath hydrological area), groundwater recharge (excluding the Copco and Iron Gate hydrological subareas), freshwater replenishment, navigation, hydropower generation, contact and non-contact water recreation, commercial and sport fishing, aquaculture, warm and cold freshwater habitat, estuarine habitat (Lower Klamath River hydrological area only), wildlife habitat, rare, threatened or endangered species, migration of aquatic organisms, spawning, reproduction, and/or early development of fish, and Native American culture (Middle Klamath hydrological area from Seiad Valley to the Pacific Ocean) (Basin Plan, 1993, as amended).

Table 3-24 shows state water quality criteria and objectives. In addition, Cal Fish & Game's management plan for the 6-mile portion of the peaking reach from the Oregon border to Copco reservoir has water quality goals consistent with its designation as a Wild Trout Area (discussed further in section 3.3.3, *Aquatic Resources*). Temperatures in this reach are not to exceed 21.1?C on an instantaneous basis and not to exceed 15.6?C for longer than 12 hours (Rogers et al., 2000).

The Oregon 2002 303(d) list reported that the Klamath River from upper Klamath Lake to the California state line was impaired because of pH, ammonia, nutrients, temperatures, dissolved oxygen (DO), and chlorophyll *a* that do not meet applicable standards (Oregon Environmental Quality, 2002). The California 2002 303(d) list reported that the entire length of the Klamath River was impaired from the state line to the river's confluence with the Pacific Ocean because of nutrients, organic enrichment, DO, and temperatures that do not meet applicable numerical or narrative water quality objectives (Water Board, 2002).

Water quality in the project area (i.e., downstream of Link River dam) is strongly influenced by the quality of water entering the Klamath River from not only Upper Klamath Lake, but also Lost River and Klamath Straits drain, in addition to its residence time within project impoundments. During wet months, sources other than the Link River provide about one-third of the total flow reaching Iron Gate dam; in midsummer, these sources may account for up to half of the total water reaching Iron Gate dam. As such, source water of diverse quality influences the quality of the water within the project-affected reaches (NAS, 2004).

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[36]The Basin Plan divides the Klamath River into two hydrological areas, the middle and lower Klamath River. The middle Klamath River is divided into seven hydrologic subareas which cover the Klamath River from the Oregon border to the confluence with the Salmon River. Copco hydrological subarea begins at the Oregon border and terminates directly above Iron Gate reservoir where the Iron Gate subarea begins. The Iron Gate hydrological subarea ends about 2 miles below the dam above the confluence with Willow Creek. The Lower Klamath River hydrological area begins at the confluence with the Salmon River and extends to the Pacific Ocean.

Table 3-24. Applicable water quality criteria and objectives for Klamath Basin in the vicinity of the Klamath Hydroelectric Project. (Source: Oregon Environmental Quality, 2003; Basin Plan, 1993)

Constituent	Oregon Criteria	California Objectives
Temperature[a]	7-day average maximum (max) not to exceed 20°C in waters designated for redband trout. Designated cool water habitat may not be warmed more than 0.3°C above ambient temperatures unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.[b] If the natural thermal potential of a water body exceeds applicable criterion, the natural thermal potential becomes the applicable criterion. A cumulative temperature increase of 0.3°C above the applicable criterion is allowed in all waters.	Shall not be altered unless demonstrated that such alteration does not adversely affect beneficial uses. At no time shall temperature be increased by more than 5°F above natural receiving water temperature.
Dissolved Oxygen	At Oregon Environmental Quality's discretion, for waters designated for cool-water aquatic life, 30-day (D) mean minimum (min) 6.5 mg/L, 7-D mean min 5.0 mg/L, and absolute min 4.0 mg/L. At Oregon Environmental Quality's discretion, for waters designated for cold-water aquatic life, 30-D mean min 8.0 mg/L, 7-D min mean 6.5 mg/L, and absolute min 6.0 mg/L. Not less than 11.0 mg/L in active spawning areas used by resident trout species unless the minimum spatial median intergravel dissolved oxygen is 8.0 mg/L or more, in which case the criterion is 9.0 mg/L.	Minimum of 7.0 mg/L above Iron Gate dam and 8.0 mg/L below Iron Gate dam and 50% or more of the monthly means in a calendar year must be above 10.0 mg/L from the state line to the Pacific Ocean on the Klamath River. The portions of Jenny and Fall creeks in California (and all other streams in the Middle Klamath hydrologic area) must be above the minimum of 7.0 mg/L and 50% or more of the monthly means must be above 9 mg/L.
Nuisance phytoplankton growth (Oregon) and nutrients (California)	If chlorophyll *a* exceeds an action level of 0.015 mg/L,[c] Oregon Environmental Quality may conduct studies to determine impacts, causes, and control strategies. Where natural conditions exceed the action level, the action level may be modified to an appropriate value.	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths sufficient to cause nuisance or adverse effects.
pH	Values shall not fall outside the range of 6.5-9.0.[d]	Values shall not fall outside the range of 7.0-8.5.
Toxic Substances (including ammonia)	Shall not exceed criteria listed in OAR 340-041-0033, Table 20. Ammonia, as recommended by the EPA: At 20oC, the long term criteria (30 day average) when fish early life stages are present, (pH between 9.0 and 6.5) range from 0.34 mg/L to 4.68 mg/L. Acute criteria (pH between 9.0 and 6.5) range from 0.885 mg/L to 32.6 mg/L when salmonids present.	All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in, human, plant, animal, or aquatic life. The Basin Plan uses the EPA recommended criteria for ammonia listed in the adjacent column.
Turbidity (NTU)	Except for certain limited duration activities, no more than a 10 percent increase above natural background levels, as measured relative to a control point immediately upstream of the turbidity causing activity.	No more than 20 percent increase above natural background levels (except as otherwise allowed by permit or waiver)

Constituent	Oregon Criteria	California Objectives
Sediment		Suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered to cause nuisance or adversely affect beneficial uses.
Total Dissolved Gas	Shall not exceed 110 percent saturation[e] Shall not exceed 105 percent saturation in water < 2-feet deep	
Specific Conductance	Unless otherwise authorized by Oregon Environmental Quality, specific conductance shall not exceed a guideline value of 400 micromhos (measured at 77°F) at the Oregon-California border (RM 208.5).	At 77°F, 90% or more of the monthly mean values must be less than or equal to 425 micromhos and 50% of the values must be less than 275 micromhos above Iron Gate dam. Below Iron Gate dam 90% of the monthly mean values must be below 350 micromhos and 50% of the monthly mean values must be below 275 micromhos.
Taste and Odor	Creation of tastes or odors deleterious to aquatic life, potability of drinking water, or palatability of fish or shellfish may not be allowed	Shall not contain taste or odor producing substances that impart undesirable taste or odors to fish flesh or adversely affect beneficial uses.
Color	Objectionable discoloration may not be allowed	Waters free of coloration that adversely affects beneficial use
Floating Material	Objectionable floating solids are not allowed	Shall not contain floating solids, liquids, foams or scum that adversely affect beneficial uses.
Naturally Occurring Conditions	Less stringent natural conditions that exceed a numeric criterion become the standard	

[a] NCRWQCB has proposed amendments to the Basin Plan that would revise the instream water quality objectives for temperature and DO to fully protect salmonids by providing specific biologically based objectives for each salmonid life stage.

[b] Exceedances of temperature criteria are not violations if they occur during the warmest 7-day period of the year that exceeds the 90th percentile of the 7-day average daily max air temperature calculated in a yearly series over the historic record. Project related waters designated by Oregon Environmental Quality for redband trout include the Klamath River from Keno dam to the California state line including the J.C. Boyle bypassed and peaking reaches, and the Oregon portions of Fall, Jenny, and Spring creeks.

[c] Calculated from a minimum of three samples collected in any 3 consecutive months at a minimum of 1 representative location (e.g., mid river or deepest part of lake) from samples integrated from the surface to a depth twice the Secchi depth or the bottom, which ever is lesser of the two. The regulations also state that the standards could be met under any other methods approved by Oregon Environmental Quality.

[d] Exceedance of this criterion is not a violation if it occurs in waters impounded by dams existing on January 1, 1996, provided all practicable measures have been taken to bring pH into compliance.

[e] Exceedances of TDG criteria are not violations if they occur when stream flow exceeds 10-year, 7-day average flood.

Temperature

Oregon and California listed the Klamath River from Upper Klamath Lake to the Pacific Ocean, the Lost River, and Klamath Straits drain in 2002 on their respective 303(d) lists as temperature impaired. Monthly sampling results from March through November compiled by PacifiCorp indicate that water temperatures below Keno reservoir are typically below 10$^{?}$C in March (table 3-25). Average summer temperatures (June, July, August, and September) over 20$^{?}$C were observed along the Klamath River at almost all sampling sites during at least July and August. Water temperatures in Upper Klamath Lake and Link River are at or above 20$^{?}$C from June through September. Water temperatures increase slightly in Keno reservoir due in part to the relatively shallow nature of the reservoir which enhances solar warming and warm agriculturally influenced water inputs from the Lost River and Klamath Straits drain. Average water temperatures below Keno dam were slightly cooler as the reach becomes steep, free flowing, and receives groundwater inputs.

In addition to the collection and compilation of longitudinal water temperature data for river reaches, PacifiCorp also conducted vertical water temperature profile monitoring near the dams in the major project reservoirs from 2000 through 2003. The results show that the shallow, upstream reservoirs (Keno and J.C. Boyle) do not exhibit long term, stable thermal stratification in the summer, and the difference between surface water temperatures and the bottom is typically less than 2$^{?}$C.

Temperatures in the J.C. Boyle bypassed reach are modified by the contribution of about 250 to 300 cfs of groundwater spring flow within the reach. The associated cool water input from the bypassed reach during the summer, combined with the fluctuation in discharge from the J.C. Boyle powerhouse during normal operations, results in an increase in the daily water temperature range in the Klamath River in the peaking reach (figure 3-22, top plot). The diurnal pattern of water temperature variation is similar to sites not affected by peaking operation. The range of daily water temperature variation below the powerhouse is greatly reduced, relative to unaffected sites, under conditions of constant daily discharge (figure 3-22, lower plot).

PacifiCorp's vertical temperature profiles near the dams at Copco and Iron Gate reservoirs are based on continuously recording meters placed at 1 meter intervals from the surface to near the bottom. The profile data show seasonal (spring through fall) thermal stratification of both reservoirs into three layers: (1) the warm, upper layer referred to as the epilimnion; (2) the metalimnion, which has a strong thermal gradient; and (3) the cold, deep hypolimnion. The epilimnion begins to form in early spring, reaching maximum temperatures approaching 25°C during late July, and then gradually cools to winter minimum temperatures typically around 5°C. Year-round temperatures in the deeper portions (the hypolimnion when the reservoir stratifies) of Iron Gate reservoir typically remain below 10°C. The depth of the metalimnion varies by season, expanding as surface temperatures rise. By mid-summer, the depth of the metalimnion is around 50 feet in both Copco and Iron Gate reservoirs. Thermal stratification begins to break down by October (figure 3-23) and by November, relatively uniform temperatures, generally between 6 and 8°C, exist throughout the water column in Copco and Iron Gate reservoirs.

The surface waters of Copco and Iron Gate reservoirs are also subject to diurnal water temperature changes as a result of solar heating and variation on the order of several days in response to changing weather patterns. Diurnal variations are not evident in the deeper waters of these reservoirs because they are isolated by the thermal gradient.

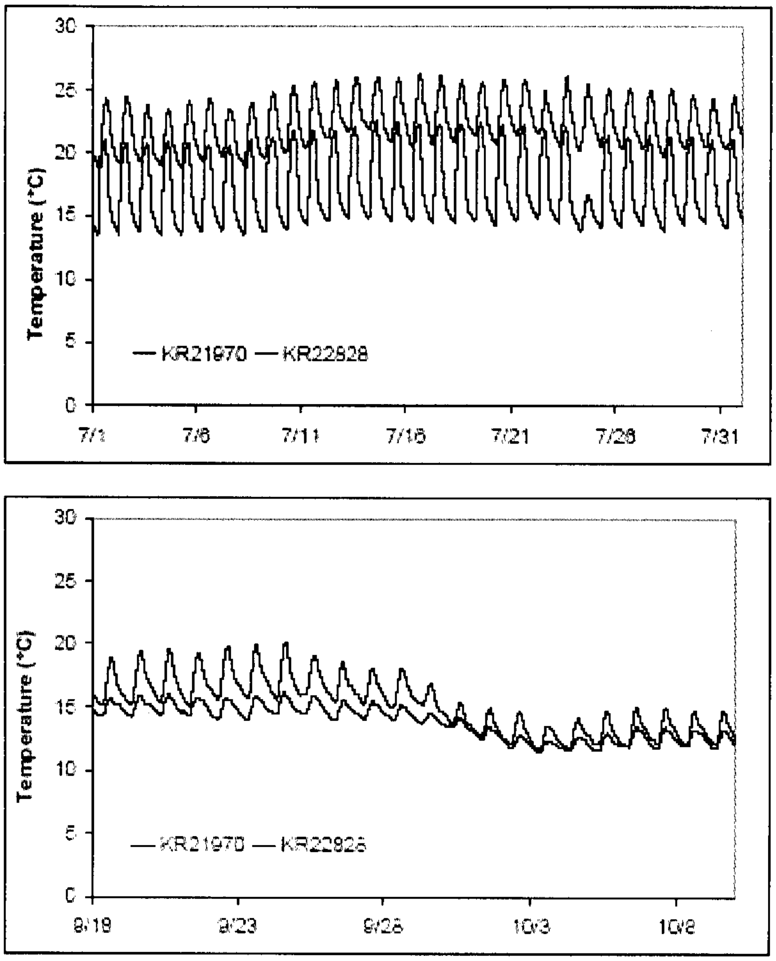
Table 3-25. Average water temperature data for stream reaches within the Klamath River Basin affected by project operation, 2000–2004. (Source: PacifiCorp, 2004a, as modified by staff).

	Average Monthly Temperature (°C)								
Station	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**
Upper Klamath Lake at Freemont St. Bridge	7.3	18.6	12.9		20.4		21.1		
Link River[a]	7.7	10.2	12.8	18.6	22.3	21.4	17.5	13.1	5.6
Klamath Irrigation Project[b]			12.9	18.4	22.2	22.3	18.4	12.5	6.7
Keno reservoir[c]	7.8	9.4	12.9	18.7	22.4	20.8	18.0	12.8	7.3
Klamath River below Keno dam	8.2	10.6	13.7	19.9	23.2	21.1	16.9	14.1	5.6
Klamath River above J.C. Boyle reservoir	8.9	11.2	13.5	20.3	22.2	21.1	16.6	14.3	5.5
J.C. Boyle reservoir at log boom (top 8m)	7.7	11.9	13.5	19.7	21.9	22.5	17.2	12.8	6.2
J.C. Boyle bypassed reach, directly below J.C. Boyle dam	7.7	11.2	14.4	20.7	23.3	21.7	16.5	13.5	6.1
J.C. Boyle bypassed reach (bottom of reach)	9.7	10.8	12.0	14.8	15.8	14.9	12.7	12.0	9.0
J.C. Boyle powerhouse tailrace	7.9		13.7	13.1	22.0	21.8	16.7		11.2
Klamath River near state line (peaking reach)			12.8		18.7		14.0		
Klamath River below state line (peaking reach)			12.8		21.1		15.2		
Klamath River above Shovel Creek (peaking reach)	8.0	9.9	16.6	19.0	19.3	18.5	15.2	11.4	7.1
Copco reservoir (top 8 m) near Copco	7.2	12.1	15.1	19.8	21.9	22.2	18.1	15.3	9.1
Copco reservoir outflow	7.6	11.3	15.0	19.8	21.4	21.4	17.6	15.2	8.9
Fall Creek	9.8	8.8	10.2	12.7	12.5	13.3	10.1	11.1	8.9
Jenny Creek	6.4	11.7	14.5	19.6	22.2	22.5	19.5	16.2	10.5
Iron Gate reservoir (top 9 m) near Hornbrook	6.4	11.7	14.9	19.7	22.3	22.6	19.2	16.2	10.6
Iron Gate dam outflow			17.0	23.2	25.2	24.5	17.8	15.9	10.8
Klamath River upstream of Shasta River	8.0	5.4	10.8	16.7	20.8	20.7	13.0	13.1	7.2

[a] Sampling points include Link River near East Side powerhouse and Link River at mouth.

[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F. During March and April, only a single temperature reading was taken, and we do not consider those values to be representative of the average monthly inflow from the Klamath Irrigation Project; consequently, we do not report them.

[c] Sampling points include south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.



Note: KR22828 (upper curve in both plots) – Klamath River above J.C. Boyle reservoir, KR21970 (lower curve in both plots) – Klamath River at the USGS gage below J.C. Boyle powerhouse.

Figure 3-22. Water temperatures measured above and below the J.C. Boyle development during peaking operation (top) and during non-peaking flow (bottom), 2002. (Source: PacifiCorp, 2004a)

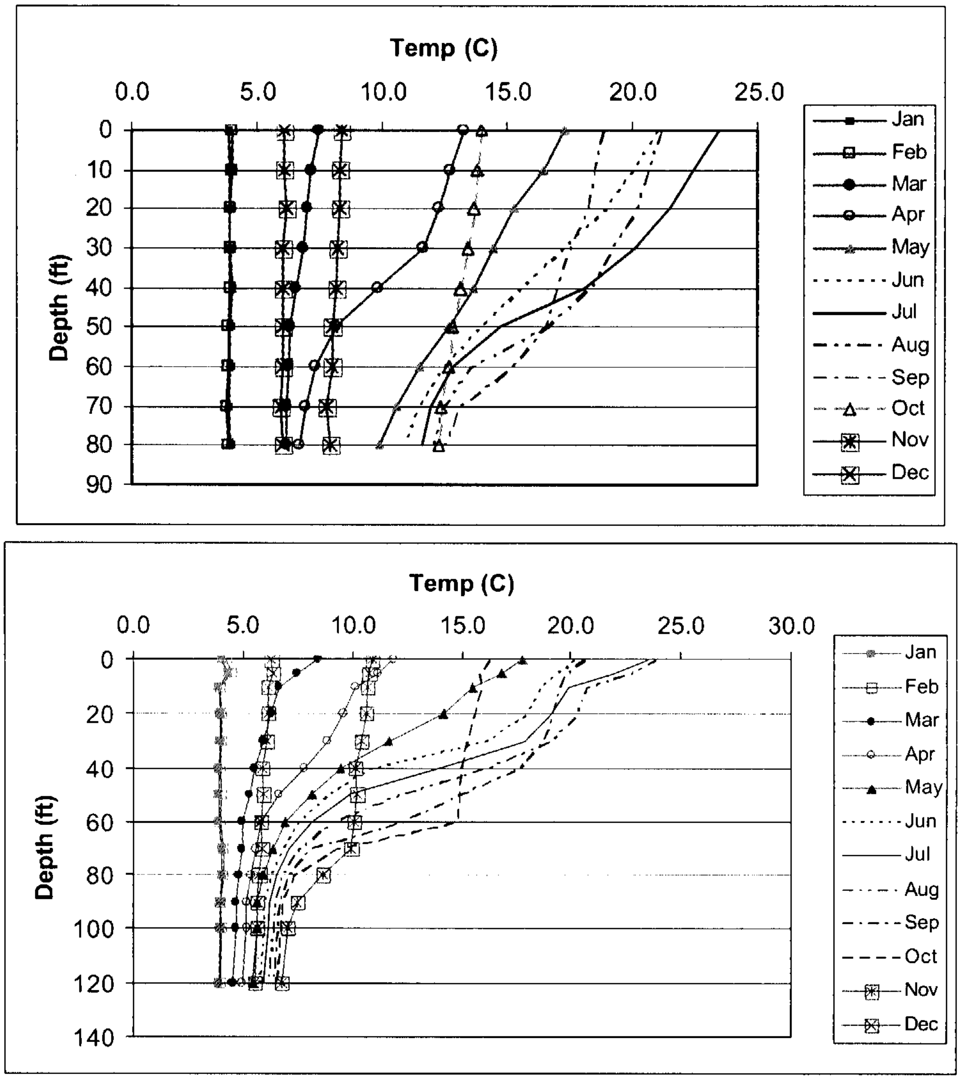


Figure 3-23. Average monthly temperature profiles for Copco (2002-top) and Iron Gate (2001-bottom). (Source: PacifiCorp, 2004a, as modified by staff)

The bottom of the Copco powerhouse intake structure is about 32 feet below full pool, and the bottom of the Iron Gate intake structure is about 30 feet below full pool. This results in water that passes through the Copco and Iron Gate powerhouses typically originating from the epilimnion during periods when the reservoirs are stratified. Figure 3-24 illustrates the close correlation of the water temperature discharged from the Iron Gate powerhouse to the water temperature measured 10 feet below the surface (epilimnetic water) immediately upstream of Iron Gate dam during the late fall and early spring months. Examination of PacifiCorp profile data indicates that, during the summer and early fall months when the reservoir is stratified, temperatures in the outfall are comparable to (within a few degrees of) water at depths between 10 and 30 feet in Iron Gate reservoir.

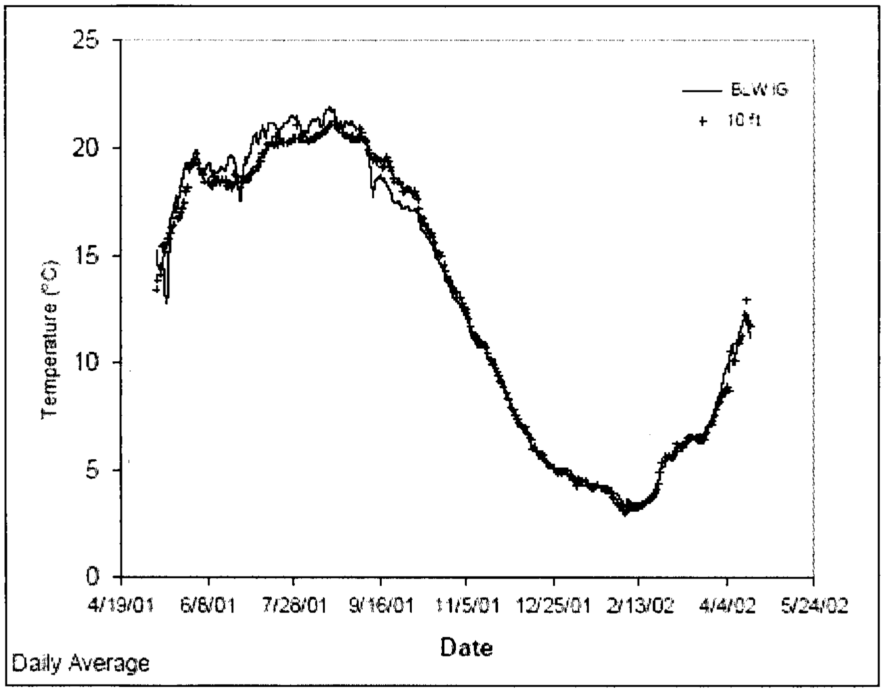


Figure 3-24. Daily average water temperature data from below Iron Gate dam and from a depth of 10 feet in the Iron Gate reservoir. (Source: PacifiCorp, 2004a)

PacifiCorp monitored the temperatures in Fall and Jenny Creeks in 2002 and Spring Creek in 2004 as part of the relicensing sampling effort to characterize the thermal regime. Fall Creek is generally cold year-round and did not exceed 14°C degrees during the summer. Temperatures in Jenny Creek experience strong seasonal variability. Monthly sampling results indicate that the creek warms from less than 10°C in the spring to above 20°C in July and August (see table 3-25), which corresponds to the period of the lowest flows of the year. The 7-day average daily maximum in Jenny Creek above the Spring Creek confluence exceeded 25°C during the warmest part of the year. PacifiCorp monitoring in Spring Creek below the diversion point indicated that temperatures never reached 20°C (PacifiCorp, 2004i). PacifiCorp concluded that, when it stopped diverting water from Spring Creek, water temperatures decreased by between 1 and 2°C in Jenny Creek below the Spring Creek confluence with Jenny Creek; but that the actual benefit to Jenny Creek appears localized.

EPA has organized temperature data compiled for Klamath River TMDL[37] model development to present statistical trends in the data (mean, minimum, maximum) at sites downstream of Iron Gate dam. Figures 3-25 through 3-27 show the mean, minimum, and maximum water temperatures for seven sites below Iron Gate where there were more than 10 samples for each of the critical months of June, July, and August. In June, water temperatures range from about 16 to 22°C, while in July, temperatures range from 16 to 26°C. In August the minimum temperatures are higher but the maximum temperatures are lower than in July.

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[37]Section 303(d) of the Clean Water Act requires that states establish a TMDL for any waterbody designated as water quality limited (CWA 303[d] list). TMDLs are written plans with an analysis that establishes what steps will be taken so that waterbodies will attain and maintain water quality levels specified in water quality standards.

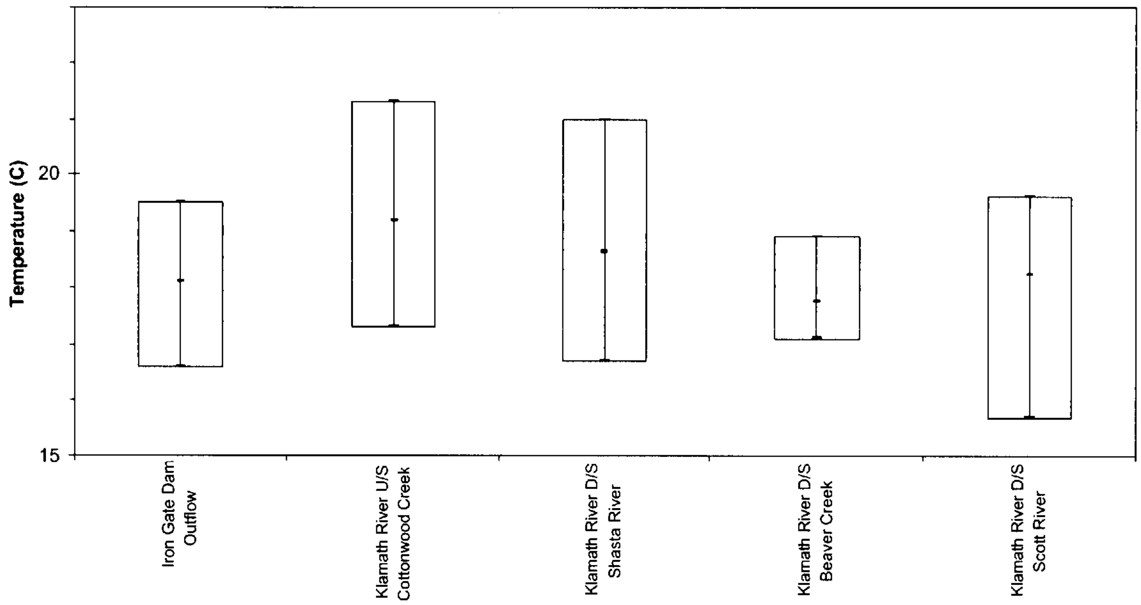


Figure 3-25. June minimum, average, and maximum temperatures along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff).

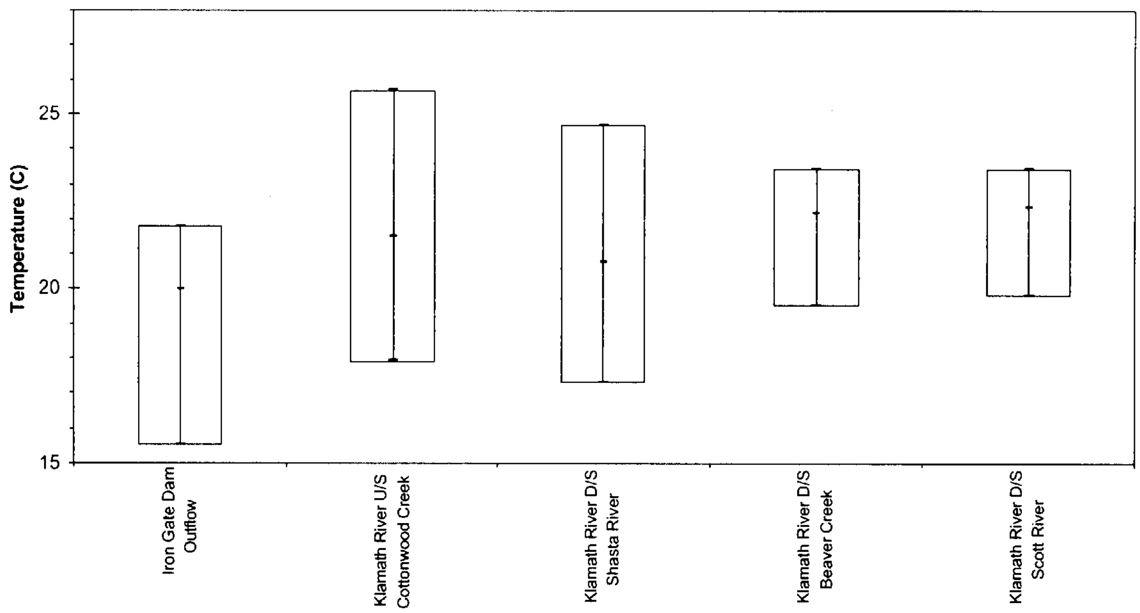


Figure 3-26. July minimum, average, and maximum temperature along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

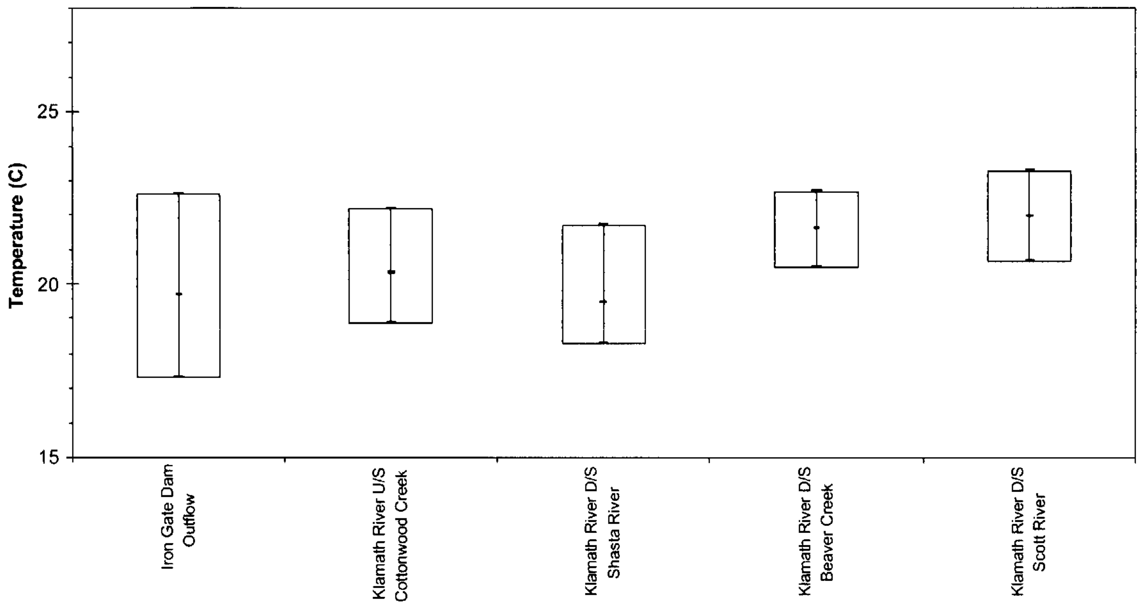


Figure 3-27. August minimum, average, and maximum temperature along the Klamath River in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

Dissolved Oxygen

Generally, average DO concentrations from samples near the surface are in compliance with applicable criteria; however, seasonal DO concentrations are quite variable (table 3-26). DO concentrations in Upper Klamath Lake respond to the primary production and respiration needs of the algal blooms and the biological oxygen demand from the aerobic decomposition of organic material in the water and, to a lesser extent, the bottom substrate. Low DO levels in Upper Klamath Lake have been associated with the period of declining algal blooms, typically in late summer and fall (Perkins et al., 2000).

PacifiCorp's DO sampling results from Keno reservoir show a longitudinal gradient; DO increases from Link River to RM 241 (near the mid-point of the reservoir), then decreases to a minimum at RM 238 downstream of Klamath Straits drain, before increasing again toward RM 235, about 2 miles upstream of Keno dam (table 3-27). This longitudinal gradient persists throughout the year. Overall, DO levels in Keno reservoir from June through September are below 6 mg/L, and some sites average below 4 mg/L in July and August.

Table 3-26. Average DO data for stream reaches and the top 9 meters of reservoirs within the Klamath River Basin affected by project operation, 2000–2004. (Source: PacifiCorp, 2004a, as modified by staff)

Station	Average Monthly DO (mg/L)								
	March	April	May	June	July	Aug	Sept	Oct	Nov
Upper Klamath Lake at Freemont St. Bridge	10.5	11.7	9.8		7.1		8.0		
Link River[a]	10.8	9.7	9.4	8.7	6.8	6.5	9.2	9.3	11.5
Klamath Irrigation Project[b]	8.5	10.0	7.4	6.5	2.4	2.3	4.1	9.1	7.1
Keno reservoir[c]	12.7	6.5	8.8	8.0	4.3	4.5	6.2	5.5	6.8
Klamath River below Keno dam	10.9	10.4	9.9	8.8	6.8	7.4	9.2	7.1	10.9
Klamath River above J.C. Boyle reservoir	10.4	10.4	9.9	8.6	7.3	8.2	8.7	8.3	12.5
J.C. Boyle reservoir at log boom (top 8 m)	10.0	9.0	10.4	7.3	5.9	4.5	7.9	8.2	10.3
J.C. Boyle bypassed reach, immediately below the dam	11.2	10.1	9.2	8.2	6.3	7.7	9.0	8.7	11.8
J.C. Boyle bypassed reach (bottom of reach)	11.2	10.8	10.3	9.8	8.9	9.8	10.0	9.4	11.7
J.C. Boyle powerhouse tailrace	11.3		8.6	10.2	6.8	5.3	8.7		9.9
Klamath River near state line (peaking reach)			8.9		7.2		7.7		
Klamath River below state line (peaking reach)			10.1		7.5		8.5		
Klamath River above Shovel Creek (peaking reach)	11.4	11.2	9.5	8.8	9.1	9.5	9.8	9.8	11.5
Copco reservoir (top 8m) near Copco	11.2	9.9	9.4	8.7	9.4	9.8	8.3	8.7	8.6
Copco reservoir outflow	10.6	9.7	9.1	8.5	6.9	8.0	7.4	7.4	9.8
Fall Creek	10.9	11.3	10.7	10.2	10.6	10.6	11.4	8.6	11.7
Jenny Creek	12.0	12.2	10.8	9.4	9.0	9.0	10.6	8.5	12.2
Iron Gate reservoir (top 9m) near Hornbrook	12.1	10.2	10.0	8.9	7.4	8.3	7.8	7.1	7.2
Iron Gate dam outflow	12.2	10.5	10.2	9.1	8.3	8.4	7.4	7.1	8.7
Klamath River upstream of Shasta River			11.2	10.4	10.5	10.2	9.7	8.4	11.5

[a] Sampling points include: Link River near East Side powerhouse and Link River at mouth.

[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F.

[c] Sampling points include: south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.

Table 3-27. Average DO data within Keno reservoir, 2000-2004. (Source: PacifiCorp, 2004a, as modified by staff)

Station	Average Monthly DO (mg/L) in Keno reservoir								
	March	April	May	June	July	Aug	Sept	Oct	Nov
South-side bypass bridge (RM 250.79)		6.8	9.0	7.8	4.8	3.7	5.3	6.2	
Miller Island boat ramp (RM 245.89)		5.2	8.6	8.5	4.6	2.4	3.7	3.5	5.5
Upstream of Klamath Straits (RM 241.48)			9.2	8.9	5.6	7.6	8.6	5.6	
Directly south of hill 4315 (RM 238.28)		5.8	8.9	7.4	3.0	4.5	7.8	6.5	
Keno bridge (Highway 66) (RM 234.90)	12.7	7.3	8.5	7.9	3.7	5.0	6.7	6.0	7.5
Keno dam at log boom, near surface (RM 233.60)				8.8	7.1	3.2	6.4	4.7	6.9
Keno dam at log boom, near bottom (RM 233.60)			6.1	4.4	3.5	0.8	0.8	4.0	6.6

Table 3-28 shows average DO concentrations at three sampling locations within Keno reservoir during May, July, and October 2002. In May, the entire reservoir is fairly well oxygenated but by July the sites in the middle and downstream portions of the reservoir are experiencing low DO values at depth. In October, the reservoir at the Miller Island boat ramp site is still experiencing low DO values throughout the entire water column while further downstream at RM 238.28 the top 2 meters the average DO concentration is above 9.0 mg/L.

Table 3-28. Average DO concentrations from representative profiles in Keno reservoir during May, July, and October, 2002. (Source: PacifiCorp, 2004a, as modified by staff)

Depth (m)	Link River (mouth) RM 253.12			Miller Island boat ramp RM 245.89			Between Klamath Straits Drain and Keno dam RM 238.28		
	May	July	October	May	July	October	May	July	October
Surface	9.8	6.5	9.0	8.6	7.7	4.1	9.1	5.3	9.2
1	9.5	7.6	9.0	8.5	4.9	3.9	8.8	3.3	9.3
2	9.4	6.7	9.0	8.6	3.0	3.8	9.1	2.2	7.0
3	9.4	5.7	8.7	8.7	3.5	3.4	9.1	2.1	5.2
4					2.2	3.3	9.0	2.0	4.5
5					0.1	1.1	8.6	1.9	3.0
6								0.1	

Except for a localized area at the J.C. Boyle reservoir log boom where DO levels average less than 5.0 mg/L in July and August, DO levels were recorded near saturation in the free-flowing reach downstream of Keno dam to Copco reservoir. The operation of J.C. Boyle dam in peaking mode seems to have negligible effect on DO concentrations in the peaking reach because the free-flowing river upstream of J.C. Boyle provides ample opportunity for aeration (see table 3-26).

The thermal stratification in Copco and Iron Gate reservoirs isolates the bottom waters from the rest of the water column. Biological and sediment oxygen demand in Copco (and to a lesser extent in Iron Gate) reservoir in the summer (most likely resulting from aerobic decomposition of dead algae and other organic matter) cause the hypolimnion to lose oxygen.

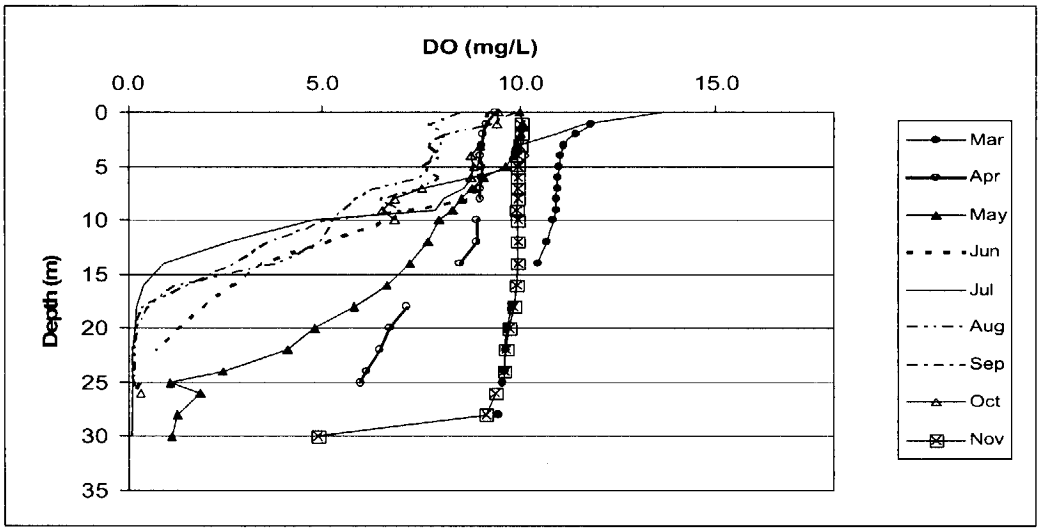
Figure 3-28 shows DO concentrations near the surface are high and near saturation at the corresponding water temperatures. However, as the summer progresses, the DO gradient between top and bottom becomes greater until the lake mixes in November. DO concentrations are similar throughout the water column as the water remains isothermal until around March when stratification begins to isolate the bottom waters. At 10 meters in Copco reservoir (approximate depth of intakes), DO concentrations in the water ranged between 4.7 and 6.8 mg/L in June, July, August, and September 2002. In Iron Gate reservoir, DO measurements taken during the same time period at 12 meters (approximate intake depth) ranged from 0.5 mg/L (September) to 6.1 mg/L (June). PacifiCorp recorded average values below the state instantaneous objective of 8.0 mg/L in September and October in the outflow from Iron Gate dam (see table 3-26). Average DO concentrations measured in the outflow from March through November ranged from 7.1 to 12.2 mg/L (six average monthly values were below 10 mg/L, which is at the limit of the annual state water quality objective; see table 3-24) with average values between June and October around 7.9 mg/L. The lowest values were observed in September and October (see table 3-26). Between the Iron Gate dam outflow and Shasta River, the water becomes oxygenated; average values in the Klamath River above the confluence with the Shasta River for June, July, and August were above 10 mg/L, with a minimum instantaneous value of 8.2 mg/L. The average DO values for September and October were 9.7 and 8.4 mg/L, respectively, showing that, at times, the river does not aerate the water to concentrations above the state's objective of 10 mg/L.

Nutrients

Water quality in the Klamath River is strongly influenced by the amount of nutrients (particularly the various forms of nitrogen and phosphorous) and algae entering project waters from Upper Klamath Lake. Sediment core studies performed by Eilers et al. (2001) concluded that Upper Klamath Lake has historically been a very productive lake with high nutrient concentrations and blue-green algae for the last 1,000 years. Walker (2001) concludes, based on sediment core analysis, that over the past 100 years the water quality of Upper Klamath Lake has changed substantially as consumptive water use practices (e.g., irrigation, municipal uses) and accompanying changes in land use practices throughout the upper Klamath and Lost River watersheds have increased. Mobilization of phosphorus from agriculture and other non-point sources (Walker, 2001), appears to have pushed the lake into its current hypereutrophic state, which includes algal blooms reaching or approaching theoretical maximum abundance. In addition, algal populations now are strongly dominated by a single blue-green algal cyanobacteria species, *Aphanizomenon flos-aquae* rather than the diatom taxa that dominated blooms before nutrient enrichment (Kann, 1998; Eilers et al., 2001). Blooms of the toxic blue green algae *Microcystis aeruginosa* have also been documented in Upper Klamath Lake (Environmental Health Perspectives, 1999)

The TMDL for Upper Klamath and Agency lakes developed in 2002 by Oregon Environmental Quality and approved by EPA identifies these interconnected lakes as hypereutrophic. They have high nutrient loading which promotes correspondingly high production of algae, which in turn, modifies physical and chemical water quality characteristics that can directly diminish the survival and production of fish populations. The TMDL identifies phosphorous loading targets as the primary strategy in improving water quality.

There is considerable water quality data available for Upper Klamath Lake, particularly from the past decade as Oregon Environmental Quality prepared the Upper Klamath Lake TMDL. Total phosphorus concentrations in Upper Klamath Lake and its outflow to the Klamath River can exceed 300 µg/L (figure 3-29).



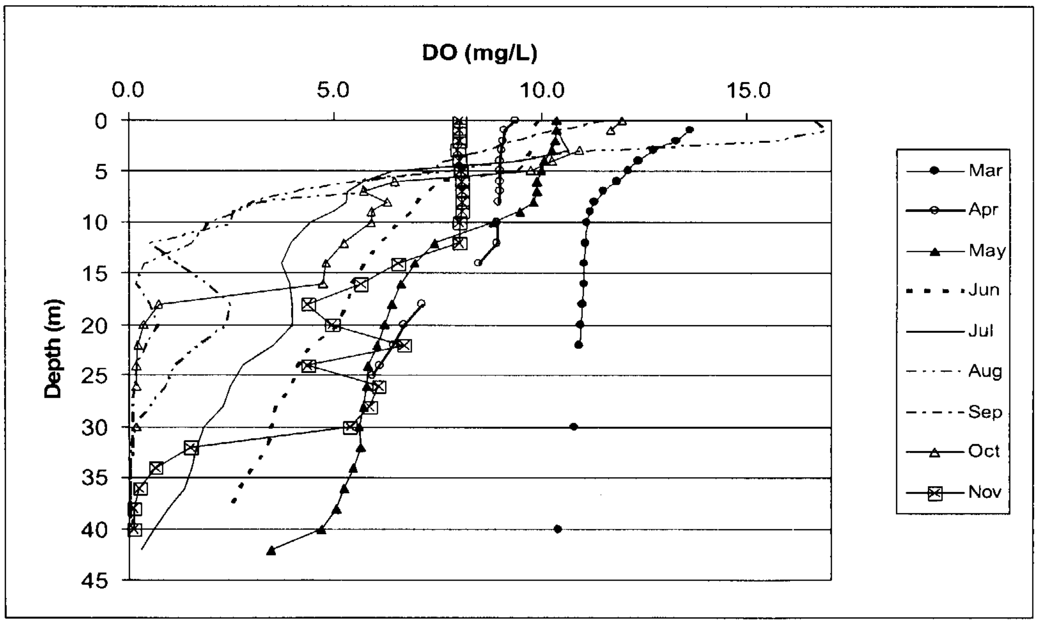


Figure 3-28. Average DO concentrations at 1 meter intervals in Copco (top) and Iron Gate (bottom) reservoirs from March through November, 2002. (Source: PacifiCorp, 2004a, as modified by staff)

Total phosphorus in Upper Klamath Lake tends to rise during spring and remains elevated through summer (figure 3-30). Oregon Environmental Quality (2002) reports that the spring rise in total phosphorus results mainly from increases in phosphorus loading during spring runoff events from sources external to the lake and that the continued high concentrations in outflow during summer is the result of internal loading to lake waters from nutrient rich sediments and algal bloom die-offs. Oregon Environmental Quality reports that the fall period is when phosphorous levels drop due to phosphorous settling out of the water column into the sediments. On an average annual basis, external sources make up 39 percent and internal sources make up 61 percent of the total phosphorus load (Oregon Environmental Quality, 2002).

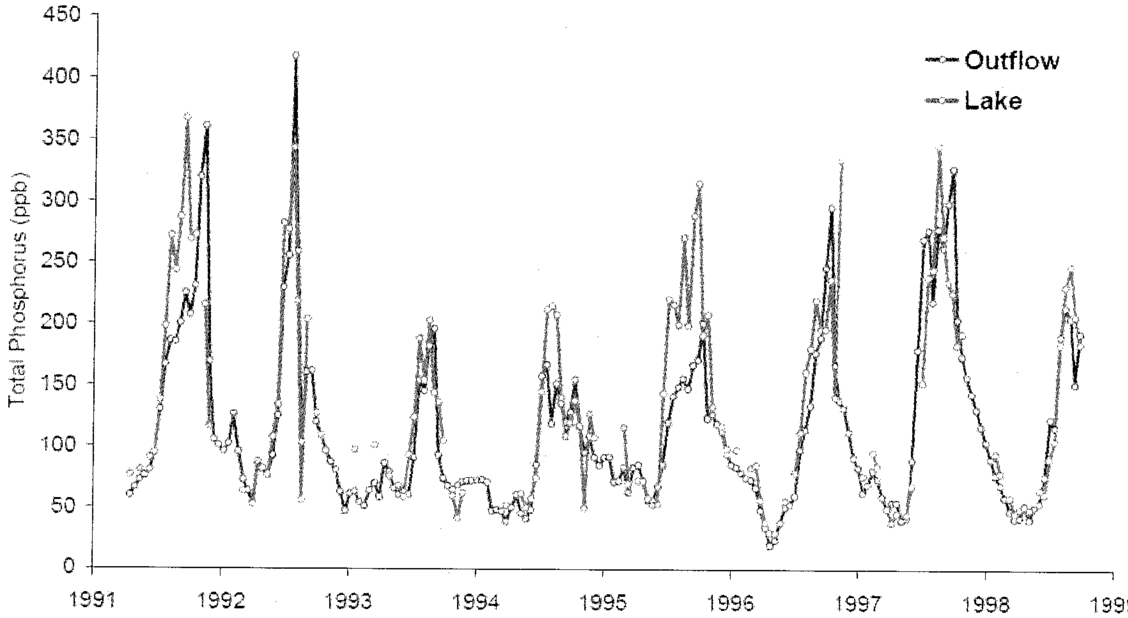


Figure 3-29. Total phosphorous values measured during 1991 to 1999 in Upper Klamath Lake and its outflow. (Source: Oregon Environmental Quality, 2002)

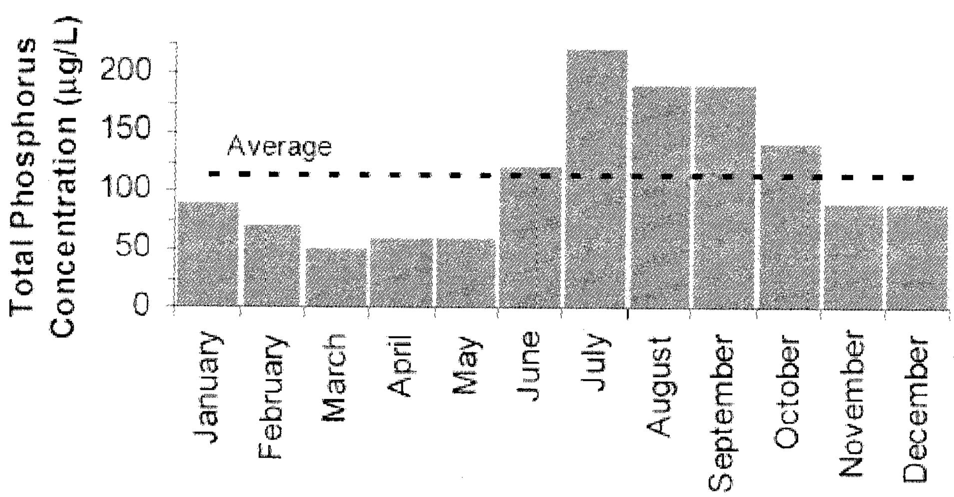


Figure 3-30. Upper Klamath Lake mean total phosphorus concentrations (1991 – 1998). (Source: Oregon Environmental Quality, 2002)

Upper Klamath Lake is also a seasonally substantial source of nitrogen (Kann and Walker, 2001; Oregon Environmental Quality, 2002). The primary source for this nitrogen loading is from nitrogen fixation by *Aphanizomenon*. Oregon Environmental Quality (2002) reports that the average outflow total nitrogen load was about 3.5 times the inflow load from 1992 to 1999. Another potential source is the mobilization of inorganic nitrogen from lake sediments during anaerobic bacterial decomposition.

Water quality in the project-affected reaches of the Klamath River exhibits the characteristics of its source waters—Upper Klamath Lake and agricultural returns into Keno reservoir. Agricultural returns

have substantial amounts of sediments, nutrients, and higher temperatures resulting from its course through agricultural fields and canals. Municipal and industrial inflows to Keno reservoir, which represent about 1 percent of the inflow, are additional sources of nutrients.

Figure 3-31 shows PacifiCorp monthly total phosphorus and orthophosphate sampling data within Keno reservoir taken in June, July, August, and September from 2000 through 2003. The data show elevated total phosphorous and orthophosphate inputs from the Klamath Straits drain, as measured at pumping plant F. Overall, total phosphorous levels in this reach are high and continue to support extensive algae abundance during the summer months (see later discussion of algae).

Downstream of Keno dam, including the J.C. Boyle development, the Klamath River generally becomes steep and free flowing, providing good mixing and aeration. PacifiCorp sampling results from the top and bottom of J.C. Boyle reservoir near the dam show no substantial difference in total phosphorous, orthophosphate, nitrate, and ammonia.

Mean total phosphorus concentrations from summer sampling is lower in the J.C. Boyle bypassed reach than at sites upstream, and gradually increases downstream reaching the highest levels observed in PacifiCorp's sampling program in the bottom of Copco reservoir (figure 3-32, top). Mean orthophosphate phosphorus concentration, although slightly lower in the J.C. Boyle bypassed reach, is not markedly different in the peaking reach or waters entering Copco reservoir than it is below Keno dam (figure 3-32, bottom). A USGS water quality study initiated in 1996 (Campbell, 2001) to characterize water quality as it affects anadromous fish production concluded that both total and ortho-phosphorus concentrations have a tendency to increase in a downstream direction from Keno to Iron Gate dams. This conclusion is consistent with PacifiCorp's 2000-2003 data.

Oregon Environmental Quality included the Klamath River on the 303(d) list of water quality-impaired water bodies with respect to ammonia, based on data collected from 1985 to 1996. Conditions of pH, temperature, and ammonia-nitrogen concentration during 2000 through 2002 were such that PacifiCorp concluded that a number of sites exceeded the EPA-recommended ammonia toxicity criterion for un-ionized ammonia.[38] Thirty-four percent (178 of 519) of ammonia samples throughout the project area in 2000 through 2002 exceeded the acute toxicity criterion. Most of those samples (64) were from Keno reservoir and water near the bottom of J.C. Boyle (19), Copco (22), and Iron Gate reservoirs (13).

According to PacifiCorp's sampling results, nitrogen undergoes somewhat more complex changes than phosphorus. Figure 3-33 shows the minimum, mean, and maximum nitrate and ammonia concentrations in Keno reservoir. Mean concentrations of ammonia are high in the upstream portion of Keno reservoir and decrease downstream with distance from Keno dam (figure 3-34) with the exception of the bottom of Copco reservoir. The pattern of mean nitrate nitrogen concentration is the converse of ammonia nitrogen. Along the Klamath River, nitrate concentrations are quite low in the upper portion of Keno reservoir above Klamath Straits drain and then increase to a high in the bottom of J.C. Boyle reservoir (mean of 0.7 mg/L). Ammonia levels that exceed between 0.232 and 6.06 mg/L on a long-term basis (30-day average continuous concentration) and 0.885 and 32.6 mg/L on a short-term basis (1 hour average) are considered toxic to aquatic life (EPA, 1999). The range of values observed in the peaking reach is fairly narrow (0.1 to 0.8 mg/L) compared to Copco and Iron Gate reservoirs downstream (figure 3-34). Results from the 1996 USGS water quality study (Campbell, 2001) showed that ammonia, total Kjeldahl nitrogen, total nitrogen and total organic nitrogen concentrations showed a strong tendency to decrease in a downstream direction and nitrate concentrations tended to increase in a downstream direction. The USGS conclusion for the nitrogen-based nutrients, specifically ammonia and nitrate nitrogen, shows some inconsistencies with PacifiCorp's results.

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[38] Ammonia toxicity depends on temperature and pH. When salmonids are present, the acute toxicity level is between 0.885 to 32.6 mg/L at 9.0 and 6.5 pH units, respectively. In general, higher temperatures and higher pH values in the water result in lower ammonia toxicity criteria.

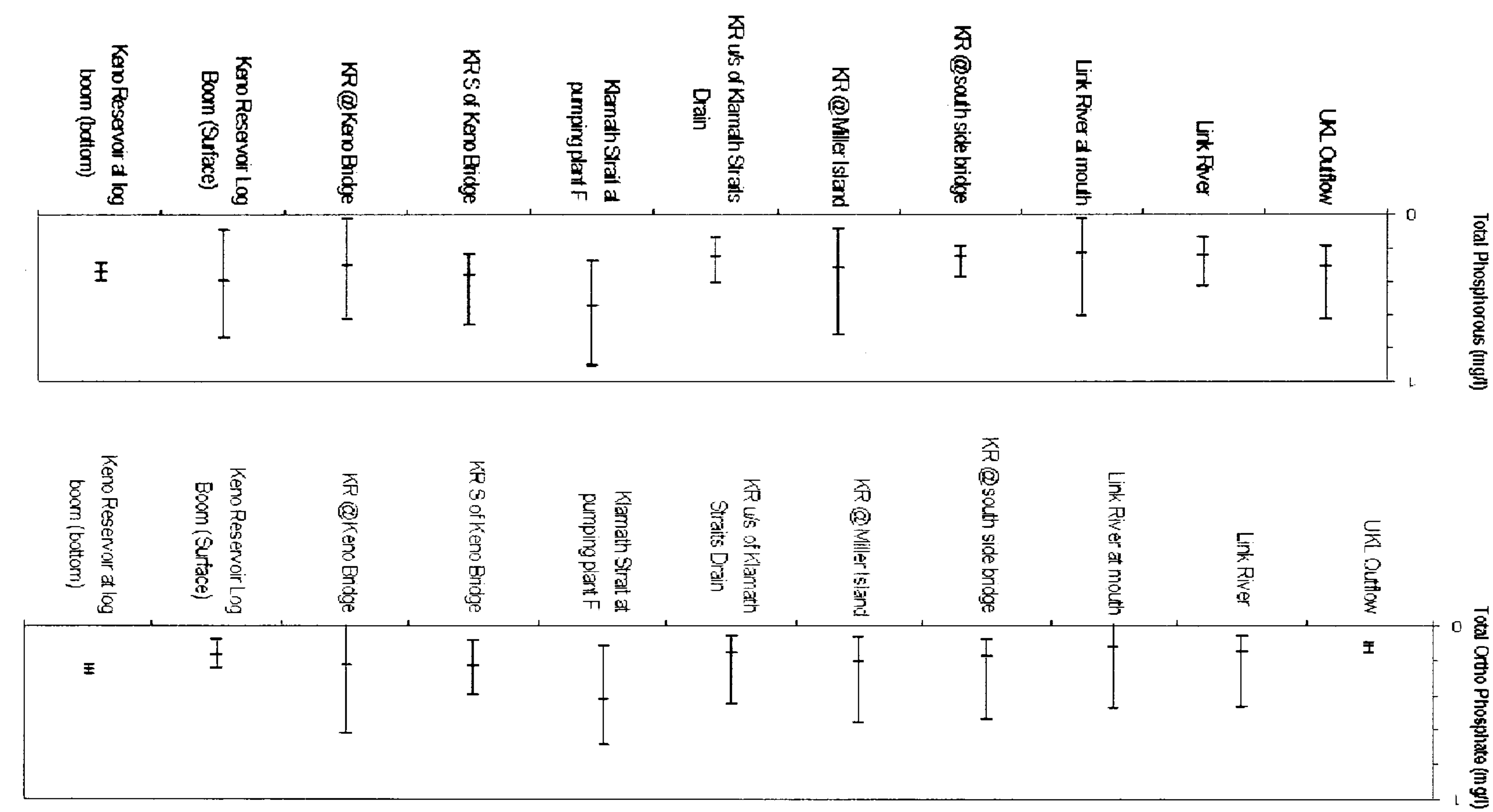

Figure 3-31. Minimum, mean and maximum total phosphorous (top) and orthophosphate (bottom) concentrations (mg/L) in the Klamath River between Upper Klamath Lake and Keno dam during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

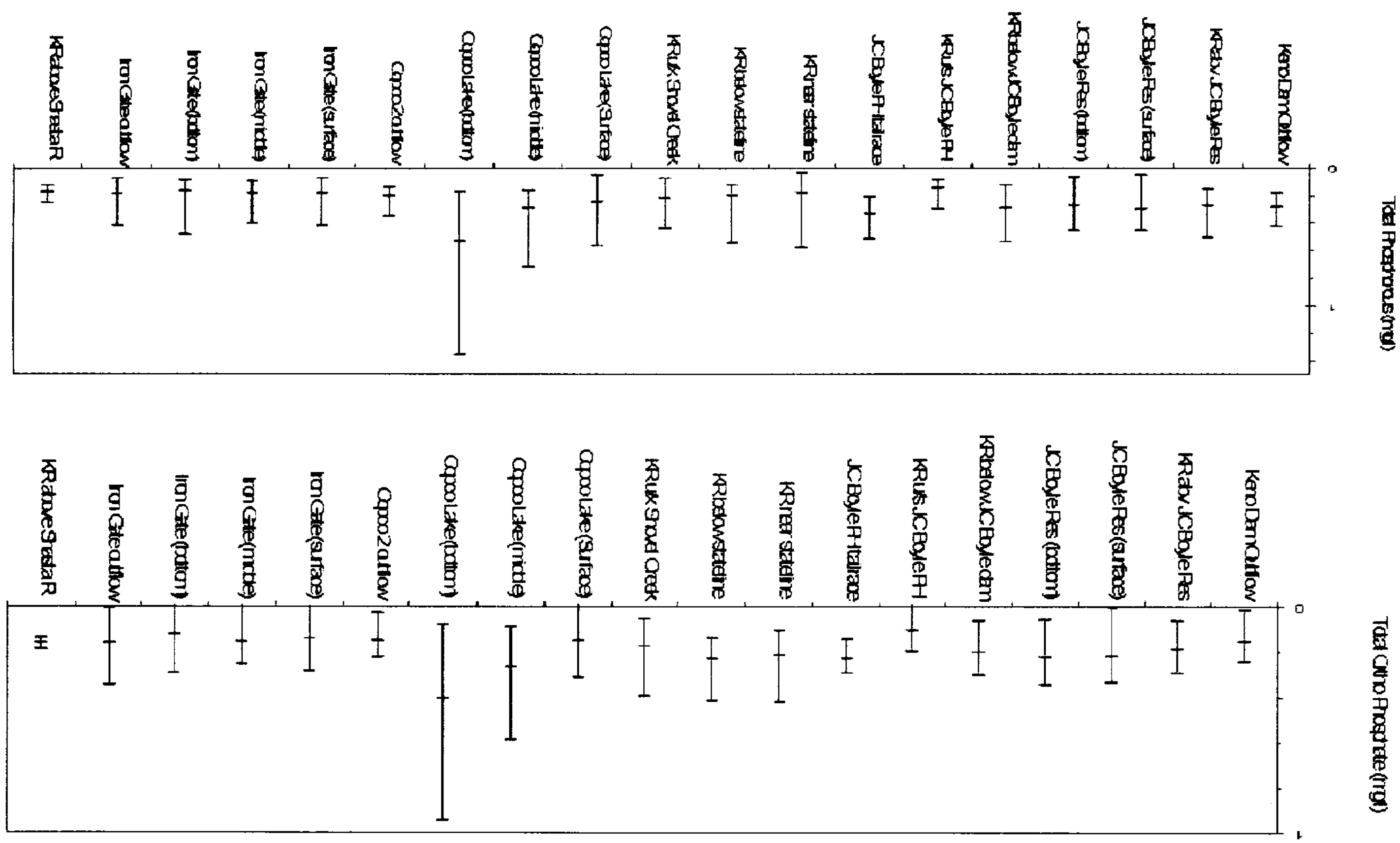

Figure 3-32. Minimum, mean and maximum total phosphorous (top) and orthophosphate (bottom) concentrations (mg/L) in the Klamath River from Keno dam to the confluence with the Shasta River during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

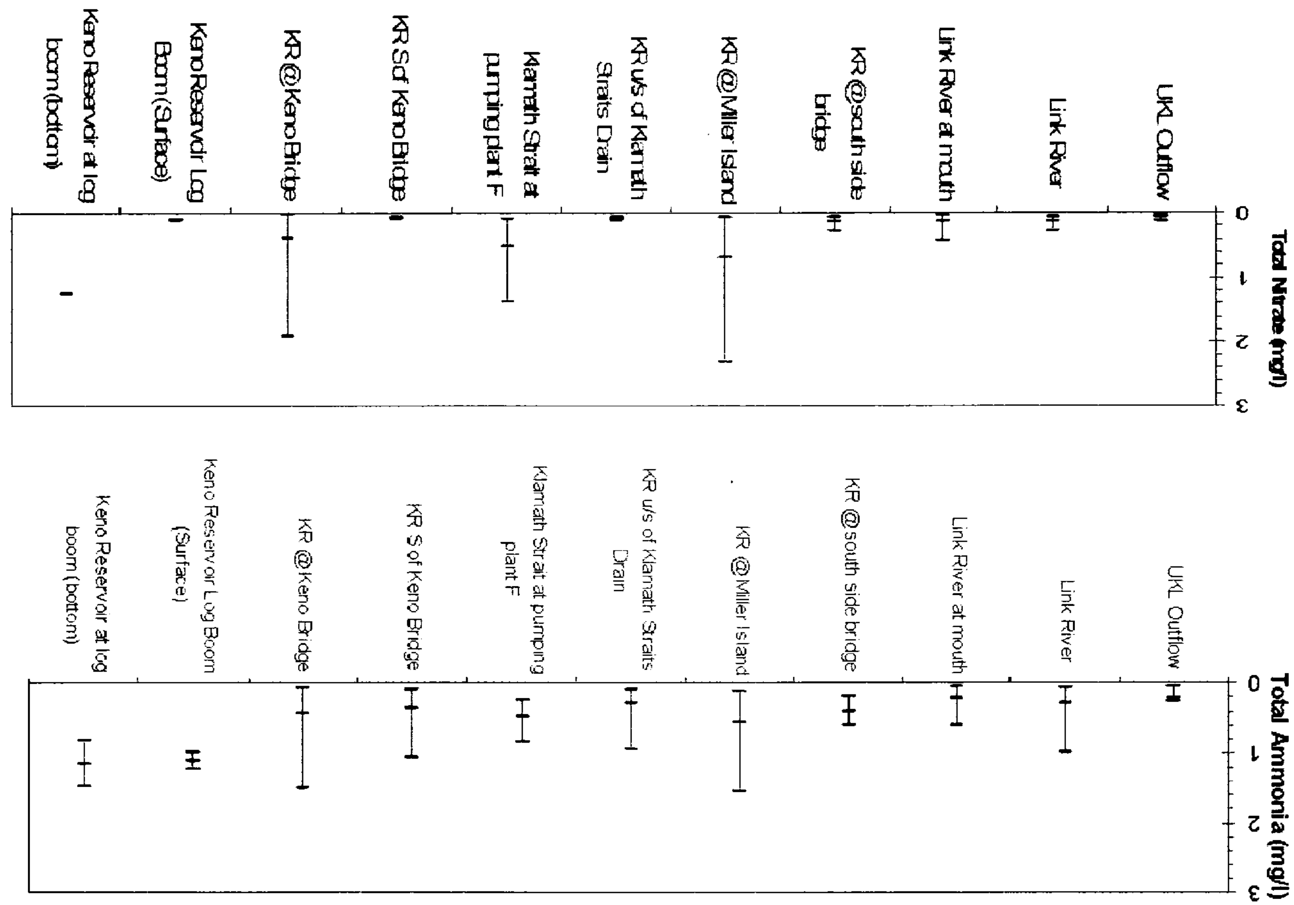

Figure 3-33. Minimum, mean, and maximum total nitrate (top) and ammonia (bottom) nitrogen (mg/L) concentrations in the Klamath River between Upper Klamath Lake and Keno dam during June, July, August, and September 2000–2003. (Source: PacifiCorp, 2004a, as modified by staff)

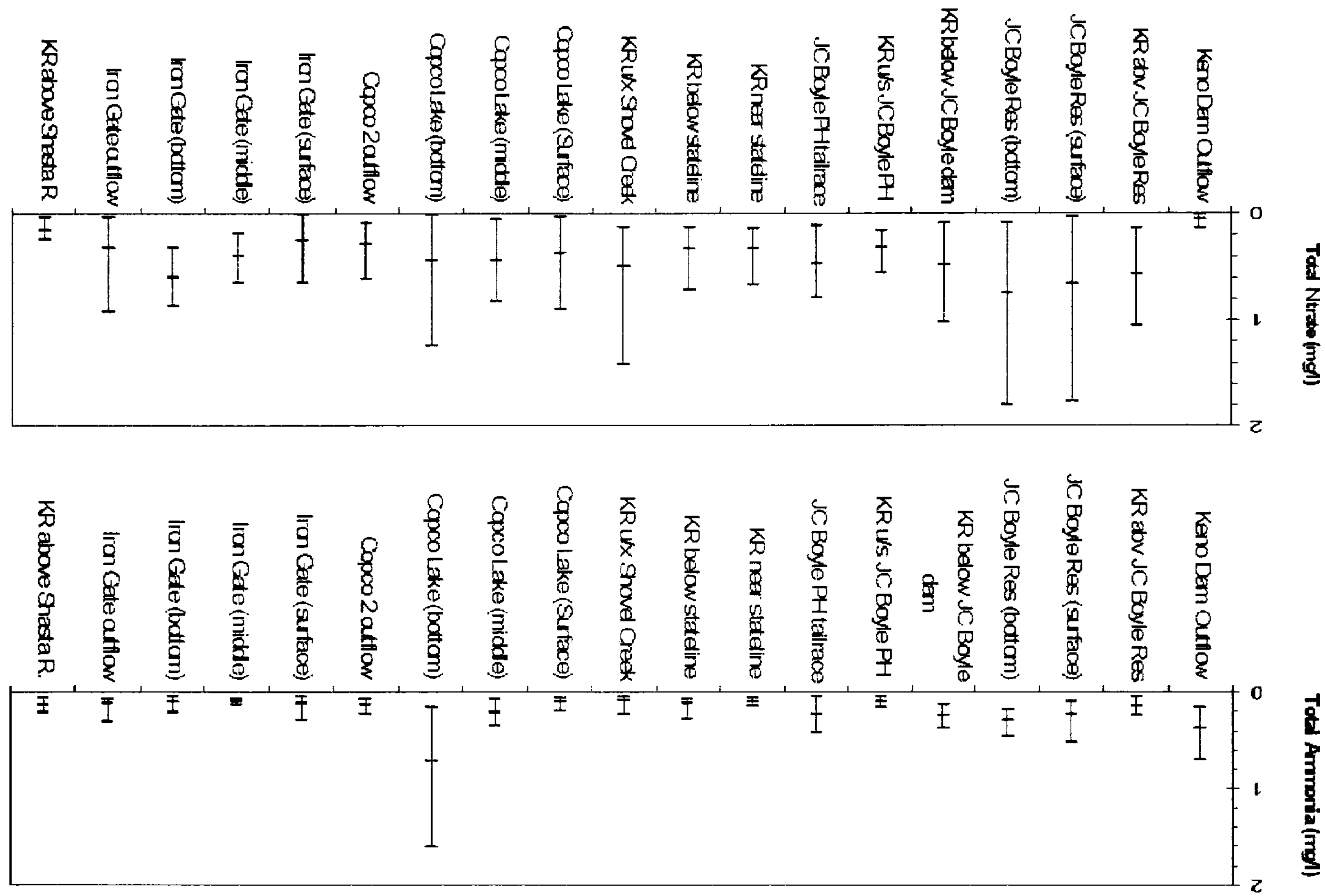

Figure 3-34. Minimum, mean, and maximum total nitrate (top) and ammonia (bottom) nitrogen (mg/L) concentrations in the Klamath River between Keno dam and the confluence with the Shasta River during June, July, August, and September 2000-2003. (Source: PacifiCorp, 2004a, as modified by staff)

Both Copco and Iron Gate reservoirs nutrient sampling results exhibit the characteristics of productive, stratified lakes. PacifiCorp's data show that Copco reservoir has a much higher annual concentration of ammonia, orthophosphate, total phosphorus, and nitrate in the hypolimnion than in the epilimnion (see figures 3-32 through 3-34). Concentrations of these constituents are at their greatest during the summer months as the reservoir thermally stratifies (table 3-29). PacifiCorp's total phosphorus sampling data from Copco reservoir indicates that the mean values from the hypolimnion are greatest in August and September (0.5 and 0.7 mg/L, respectively); however, by November, when the water column is isothermal, the concentration drops to 0.1 throughout the entire water column. In Iron Gate reservoir, total phosphorous concentrations are the same in both epilimnion and hypolimnion, or even lower in the hypolimnion than the epilimnion and at concentrations well below those seen in Copco reservoir in the summer (figure 3-32, top).

Table 3-29. Mean total phosphate, orthophosphate, and ammonia (mg/L) in Copco and Iron Gate reservoirs from samples collected between 2000 and 2004. (Source: PacifiCorp, 2004a, as modified by staff)

Station	June	July	August	September	October	November
Total Phosphorous						
Copco (top 8 m)	0.2	0.2	0.2	0.2	0.1	0.1
Copco (9-19 m)	0.2	0.3	0.3	0.2	0.2	0.1
Copco (20-32 m)	0.3	0.3	0.5	0.7	0.5	0.1
Iron Gate (top 9 m)	0.2	0.1	0.1	0.2	0.1	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (20-45 m)	0.1	0.1	0.1	0.2	0.2	0.2
Orthophosphate						
Copco (top 8 m)	0.1	0.1	0.2	0.1	0.1	0.0
Copco (9-19 m)	0.2	0.2	0.4	0.2	0.1	0.1
Copco (20-32 m)	0.2	0.3	0.4	0.6	0.5	0.0
Iron Gate (top 9 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.2	0.1	0.1
Iron Gate (20-45 m)	0.1	0.1	0.1	0.1	0.2	0.1
Ammonia						
Copco (top 8 m)	0.1	0.1	0.1	0.2	0.2	0.1
Copco (9-19 m)	0.2	0.1	0.2	0.3	0.3	0.1
Copco (20-32 m)	0.3	0.3	0.7	1.1	1.0	0.1
Iron Gate (top 9 m)	0.1	0.0	0.1	0.1	0.2	0.1
Iron Gate (9-19 m)	0.1	0.1	0.1	0.1	0.4	0.1
Iron Gate (20-45 m)	0.1	0.0	0.1	0.2	0.3	0.3

The amount of oxygen present in the water also affects nutrient chemistry. Extended periods of anoxia (low or zero oxygen) promote conditions that result in the reduction of nitrate to ammonia and can lower the oxidation-reduction potential (redox potential – a measure of the electrical potential of ions in the water) to the point that phosphorus is released from the sediment. Such conditions occur regularly in Copco reservoir, especially in August and September, but rarely in Iron Gate reservoir (PacifiCorp, 2004a). The differences in redox potential in the reservoirs are reflected in nutrient concentrations in the hypolimnion. Orthophosphate and ammonia are noticeably more abundant in the hypolimnion of Copco reservoir than in Iron Gate reservoir (figures 3-32 and 3-34 and table 3-29).

Seasonal changes in water quality constituents below Iron Gate dam are not large (table 3-30). Orthophosphate and total phosphorous concentrations are highest in March with little variability throughout the rest of the year and little difference between the two sampling locations. Ammonia

concentrations remain fairly constant throughout the year, with occasional high values in May, September, and October. Notably, ammonia values near Shasta River are considerably higher in October compared to concentrations measured below Iron Gate dam. Nitrate tends to increase slightly in the fall at both sampling locations.

Table 3-30. Water quality constituents at sites sampled downstream from Iron Gate dam. (Source: PacifiCorp, 2004a; as modified by staff)

	Iron Gate dam outflow, mean 2000-2004 (mg/L)				Above Shasta River, mean of 2002 and 2004 data (mg/L)			
Month	**TP**	**PO_4**	**NH_3**	**NO_3**	**TP**	**PO_4**	**NH_3**	**NO_3**
March	0.38	0.36	0.07	0.23				
April	0.16	0.08	0.05	0.34				
May	0.14	0.10	0.13	0.15	0.09	0.06	0.16	0.09
June	0.17	0.15	0.10	0.18	0.13	0.09	0.06	0.02
July	0.17	0.13	0.11	0.23	0.15	0.13	0.04	0.06
August	0.14	0.14	0.08	0.16	0.15	0.15	0.10	0.09
September	0.19	0.14	0.14	0.44	0.14	0.11	0.15	0.21
October	0.13	0.12	0.14	0.38	0.12	0.12	1.99	0.24
November	0.10	0.10	0.2	0.4	0.12	0.10	0.07	0.36

The ratio of total nitrogen to total phosphorus in the Klamath River system is below 7 (median = 6.6). This ratio has been used as an approximate indicator of relative nutrient limitation of phytoplankton in lakes. A ratio of N:P more than about 10:1 (by weight) generally indicates phosphorus limitation. The median N:P ratio in the project area equals 6.6:1, and only about 20 percent of all values are greater than 10:1. This condition holds from Link River dam to Iron Gate dam, which suggests that phytoplankton growth in the Klamath River is strongly nitrogen-limited. Abundant phosphorus, coupled with limited nitrogen and warm water, provides advantageous conditions for nitrogen-fixing species, so it is not surprising that the project reservoirs support blooms of the nitrogen-fixing cyanophyte, *Aphanizomenon flos-aquae*.

Sediment Oxygen Demand

PacifiCorp commissioned a sediment oxygen demand (SOD) study to analyze sediment core samples from Keno, J.C. Boyle, Copco, and Iron Gate reservoirs in 2003. More recently, Eilers and Raymond (2005) performed a similar study in Lost River and Keno reservoir to enhance current TMDL model development. USGS also commissioned SOD sampling in Keno reservoir in 2003.

PacifiCorp's study showed that SOD in project reservoirs ranged from 1.5 to 4.7 $g/m^2/day$. SOD in reservoirs above J.C. Boyle dam was all above 2.0 $g/m^2/day$, while SOD in Copco and Iron Gate reservoir was between 1.0 and 2.0 $g/m^2/day$. Results from Eilers and Raymond (2005) are consistent with PacifiCorp's work where SOD in the Lost River and Lake Ewauna ranged from 1.32 to 3.61 $g/m^2/day$. The results indicate that the oxygen dynamics of the upper study area, especially at Keno reservoir, are controlled to a large extent by the nature of the water entering the system rather than sediment/water interactions in the impounded areas. Where anaerobic conditions exist for extended periods, nutrients and other constituents can be released from the sediment, and such effects may play a larger role in water quality dynamics in the hypolimnion in Copco and Iron Gate reservoirs.

SOD rates measured by USGS in June 2003 (USGS, 2003) at 16 sites in Keno reservoir and published as provisional results ranged from 0.6 to 3.11 (median of 2.15) $g/m^2/day$. Results from the Eilers and Raymond 2005 study are consistent with results of the earlier Eilers and Gubala study and USGS (2003). PacifiCorp concludes that, although sediments exert an oxygen demand, the SOD in the water column is less than the biological demand in Keno and J.C. Boyle reservoirs.

Water enters Keno reservoir with a substantial biological oxygen demand (BOD) present, presumably derived from decomposition of the entrained cyanobacteria (Eilers and Gubala, 2003). Eilers and Gubala (2003) conclude that BOD in the waters of the Lake Ewauna (upper) portion of Keno reservoir overshadows the effects of the sediment in the lower portion of Keno reservoir and J.C. Boyle reservoir to a considerable degree. In Copco and Iron Gate reservoirs, BOD is lower and sediment effects become a more important influence on the quality of the overlying water.

Algae

Algae within the Klamath River are an important component to the overall water quality and water chemistry processes affecting water quality within the system. The seasonal blooms and die offs of algae in response to conditions within the water at various locations throughout Upper Klamath Lake and the project waters have consequences throughout the entire system. In Upper Klamath Lake, algae productivity is associated with DO that shows extreme daily variation (high during the day and low at night) and elevated pH and free ammonia concentrations that do not meet Oregon's water quality standards (Kann and Walker, 2001; Walker, 2001), and chlorophyll *a* concentrations (a surrogate measure of planktonic algae abundance) exceeding 200 µl/L are frequently observed during the summer months[39] (Kann and Walker, 2001). Carlson Trophic State Index (TSI)[40] values calculated from PacifiCorp monitoring data (based on chlorophyll *a* concentrations) for Upper Klamath Lake at the Freemont St. Bridge range from 55 in May to 77 in June.

As expected, chlorophyll *a* concentrations are higher in the reservoirs than the river sections directly upstream except for Link River. The average chlorophyll *a* concentration entering Keno reservoir from Link River is 57 µg/L with a peak concentration of 257 µg/L in July. Peak algal abundance (chlorophyll *a* concentrations near 300 µg/L) in Keno reservoir occurs in June. TSI index values based on monthly chlorophyll *a* in Keno in July, August, and September ranged from 64 to 70.

Water entering J.C. Boyle reservoir has an average chlorophyll *a* concentration of 14.5 µg/L with a peak concentration of 58 µg/l. Chlorophyll *a* concentrations steadily decrease downstream of the J.C. Boyle powerhouse. The average and peak chlorophyll *a* concentration in the peaking reach is 7.8 µg/L and 23 µg/L, respectively. Sampling results near the Copco and Iron Gate dams show that both reservoirs are highly productive. The average and peak chlorophyll *a* values at Copco reservoir were 10.7 µg/L and 44 µg/L, respectively, and at Iron Gate reservoir, 10.3 µg/L and 58.0 µg/L, respectively. The chlorophyll *a* concentrations in both reservoirs varies seasonally (figure 3-35). Generally, monthly Carlson TSI values for chlorophyll *a* decrease from upstream to downstream in Keno, J.C. Boyle, and Copco reservoirs with all values in Copco in the 40 to 50 range. TSI values in Iron Gate are slightly higher than those calculated for Copco, but within the same range. There is a predictable sequence of algal taxa in both reservoirs. During March there is typically a bloom of diatoms, followed by a period of relatively low chlorophyll abundance. Chlorophyll usually peaks in August and September when dense blooms of the nitrogen-fixing cyanophyte (blue-green alga) *Aphanizomenon flos-aquae* occur.

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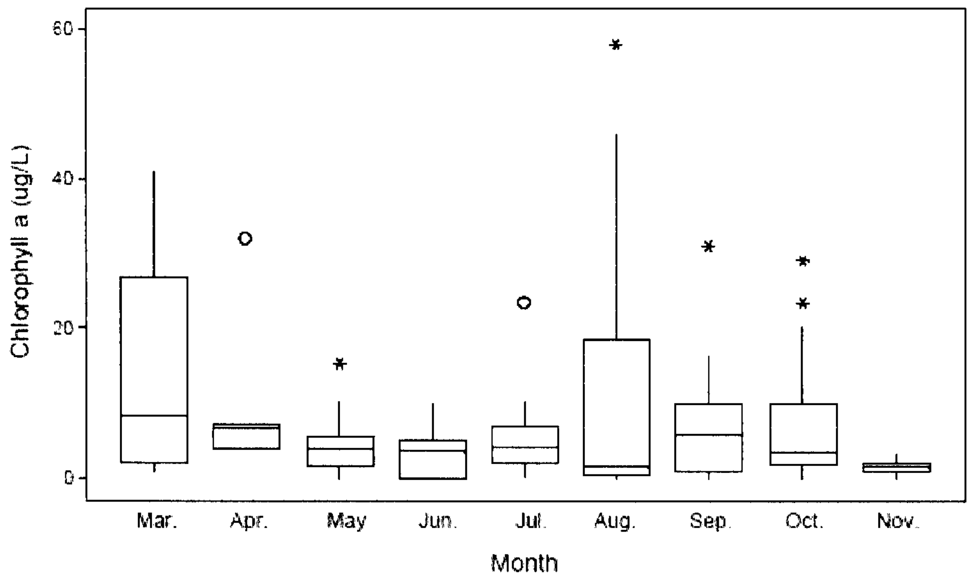
[39]The Organization for Economic Cooperation and Development has established lake classifications for various levels of biological productivity. Lakes with a mean of 25 ug/L or a peak concentration of 75 µl/L of chlorophyll *a* respectively are considered hypereutrophic (Phillip Williams and Associates, 2001). Wetzel (2001) defines freshwater lakes with concentrations of chlorophyll *a* greater than 10 µg/L as eutrophic (Wetzel, 2001).

[40]Carlson TSI is a generally accepted index of trophic status of lakes based on the relationship of the seasonal means of Secchi disk, chlorophyll *a*, and total phosphorus. Generally, the "greener" the lake, the higher the TSI number, and the lower the water visibility. Conditions are considered eutrophic when TSI values are between 51 and 70, and hypereutrophic when values are above 70.



Notes: The limits of the box enclose the central 50 percent of the distribution. The horizontal line in the middle of the box represents the median value. The vertical lines (whiskers) at the top and the bottom of the box indicate the range of "typical" data values. Whiskers extend to the largest or smallest data point that is within 1.5 times the IQR from the limits of the box. Any values beyond 1.5 times the IQR (possible outliers) are represented individually by asterisks if they are within three times the IQR, and by open circles if they are beyond three times the IQR (probable outliers)

Figure 3-35. Box plot showing the distribution by month of combined chlorophyll *a* values measured in Copco and Iron Gate reservoirs during 2000 to 2003. (Source: PacifiCorp, 2004a)

Chlorophyll *a* data filed as part of PacifiCorp's historical water quality database (part of the final license application) shows chlorophyll *a* values below Iron Gate dam. Figure 3-36 shows the monthly values for sites below Iron Gate dam available in the database. Chlorophyll *a* concentrations experience the greatest range and highest average at the station closest to Iron Gate dam. Downstream of the RM 182.38 sampling point, the mean remains relatively even while the range in reported values increases with distance downstream.

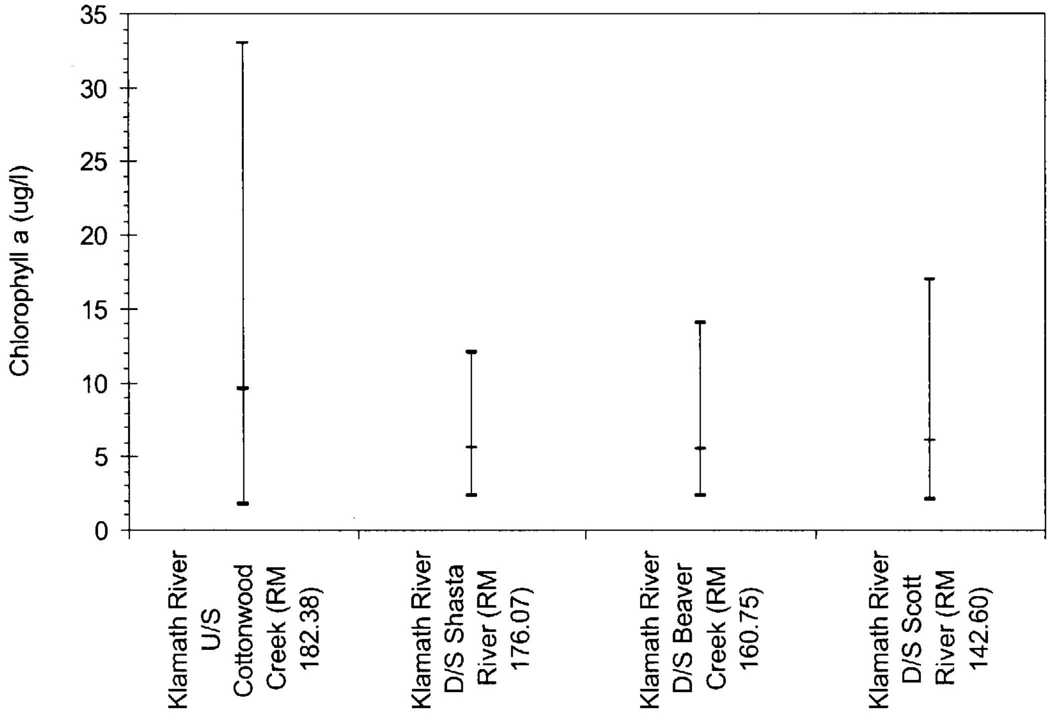


Figure 3-36. Maximum, mean, and minimum chlorophyll *a* concentrations at four stations below Iron Gate dam from data collected in 1996 and 1997. (Source: PacifiCorp, 2004a, as modified by staff)

On January 30, 2005, the Quartz Valley Indian Community filed a letter with the Commission documenting the presence of *Microcystis aeruginosa* and the liver toxin microcystin at Copco reservoir in 2004 (letter from A. Peters, chairman of the Quartz Valley Indian Community, to the Commission, dated January 30, 2005). *Microcystis aeruginosa* blooms historically have been observed in Upper Klamath Lake (Environmental Health Perspectives, 1999) and throughout the Klamath River Basin. Shoreline and open water locations within Copco and Iron Gate reservoirs sampled by Kahn et al. in 2005 exhibited the presence of the cyanobacteria *Microcystis aeruginosa*, which, in previous samples collected in September 2004 and July 2005, produced the potent hepatotoxin (liver toxin) microcystin. Although toxicity data for the most current samples are not available, it is clear from phytoplankton density data that cyanobacterial blooms have increased in intensity and extent as summer monthly sampling progressed.

Cell densities of *Microcystis aeruginosa* exceeded World Health Organization and EPA moderate risk levels[41] at all sampled stations on August 10 and 11, 2005, including at the open-water stations in front of Iron Gate (916,548 cells/mL) and Copco (151,004 cells/mL) dams. Several of the shoreline stations exceeded the moderate risk cell count level by more than 20 times (memo from Dr. J. Kahn, Aquatic Ecosystem Sciences, LLC., to the Karuk Tribe, the Water Board, and NCRWQCB, dated August 19, 2005, filed with the Commission by NCRWQCB, in its letter dated November 15, 2005). As a result of these recent samples, the Water Board issued a public health advisory (Water Board and California

[41]The World Health Organization and EPA state that, for recreational bathing waters, a moderate risk level is 50 μg/L chlorophyll *a*, 100,000 cells/mL or 20 μg/L microcystin in the top 4 meters of surface waters (Falconer et al., 1999; Chorus and Cavalieri, 2000).

EPA, 2005). The advisory stated that the concentrations of the *Microcystis aeruginosa* cyanobacteria levels and resulting microcystin toxin detected in samples collected from both shoreline and open water locations in Copco and Iron Gate reservoirs pose a significant potential threat of adverse health effects in human and animals exposed through direct ingestion of contaminated water as well as incidental ingestion during recreational water activities and bathing.

PacifiCorp also performed phytoplankton sampling from 2001 to 2004 at 21 sites along the Klamath River in the vicinity of the Klamath Hydroelectric project including Upper Klamath Lake and its tributaries. Results show that the highest mean algal abundance (measured as over 7,500 units/ml), were observed in the Klamath River at the Keno Bridge (Highway 66), Link River, Upper Klamath Lake (at Freemont St. Bridge). Results also show that the blue green algae *Microcystis aeruginosa* was found in about 12 percent of the 462 samples taken throughout the project vicinity; however, the spatial and temporal variability has not been disclosed at this time.

Attached algae and rooted vegetation within the Klamath River also play an important role in nutrient dynamics, as well as general river ecology. Because attached algae are in continuous contact with the river, the growth and distribution of the algal communities can affect nutrient fluxes and result in short-term changes in water quality parameters such as dissolved oxygen and pH. The Upper Klamath Lake TMDL recognized that aquatic plants are abundant in portions of the upper Klamath River and in areas dominated by nuisance filamentous green algae species such as *Cladophora,* an algae common in nutrient enriched waters. Field work contracted by EPA sampled 10 sites in the Klamath River below Iron Gate dam to characterize the benthic algae (periphyton) community. Results suggest that there are some major changes in the periphyton community that appear to be controlled to some degree by differences in nutrient availability (Eilers, 2005).

Species composition results showed a transition from a *Cocconeis/Diatoma*-dominated community upstream to a system heavily dominated by *Epithemia* downstream. *Cladophora* exhibited the greatest percentage of cover at the Shasta River sampling site where it represented one-half the periphyton community (by bio-volume). The study authors felt compelled to note that the biomass of periphyton was generally low to moderate, which was contrary to their expectations prior to the survey and reasoned that changes in the flow regime (possibly due to Reclamation orders) resulted in a doubling of flow from about 600 cfs around August 15 to about 1,200 cfs near the end of the month, settling at about 800 cfs by September 1, the start of the study. This increase in discharge may have been capable of dislodging filamentous algae that had proliferated under the previous lower flow regime (Eilers, 2005).

pH

The high concentration of algae in Upper Klamath Lake and Keno reservoir influences pH levels because photosynthesis and associated uptake of carbon dioxide results in high pH (basic conditions) during the day and respiration by algae and other organisms at night decreases the pH to more neutral conditions. Monthly average alkalinity (measured as $CaCO_3$) levels in Upper Klamath Lake, Link River, and Keno reservoir are fairly similar ranging between 40 and 50 mg/L with little variability throughout the sampling period. Values of 20 to 200 are typical of freshwater systems, however at lower levels freshwater systems have less buffering capacity, increasing their susceptibility to changes in pH. As expected, Link River water is more alkaline with strong seasonal trends. Concentrations ranged between 141 and 259 mg/L with the lowest levels recorded during the summer. PacifiCorp sampled pH as part of its water quality sampling program and collected almost 3,800 pH readings between March and November 2000 to 2004. Average pH values from all PacifiCorp sampling stations on the Klamath River and project reservoirs collected during the 2000 to 2003 study were between 7 and 10 standard units with the higher values coinciding with high algal densities, which typically occur from spring through fall.

Annual mean pH values show little variability between Keno reservoir and the bottom of the peaking reach. Water in Keno reservoir has an average pH of 8.2 with a peak pH of 9.4 standard units.

Average pH in J.C. Boyle reservoir is 7.8 with a peak of 9.3 standard units. Downstream of J.C. Boyle development in the peaking reach (Klamath River just above Shovel Creek) the average pH was 8.1 with a peak of 8.9 standard units.

The pH values in Copco and Iron Gate reservoirs are similar to each other in that the average pH at the surface was 8.2 and 8.1, respectively, while below 20 meters the average pH was 7.3 in Copco and 7.2 in Iron Gate with very little difference during June through September (range in Copco epilimnion was 0.7 units and 0.5 in Iron Gate). The range in the hypolimnion of both Copco and Iron Gate reservoirs during the summer was 0.2, indicating that there is little variability in pH at depth within these reservoirs during the summer. Monthly average alkalinity levels within Copco and Iron Gate reservoirs is slightly higher than those recorded in Keno, however none is above 75 mg/L.

Water Clarity

Water clarity is a function of how much suspended material exists in the water and how far light can penetrate. The depth at which light extinction occurs in lakes and reservoirs can be easily measured by using a Secchi disk, which provides an indication of the depth at which the disk is no longer visible to the naked eye. The higher Secchi depth measurements mean greater water clarity. Table 3-31 shows Secchi disk measurements at five representative locations within the project area (the mouth of Link River to Iron Gate reservoir). Water clarity is often influenced by planktonic algae, discussed earlier, and total suspended solids (TSS).

Table 3-31. Secchi depth[a] measurements at representative locations along the Klamath River in 2001 to 2003. (Source: PacifiCorp, 2004a)

Site Name	Number	Min.	Average	Max.
Link River Mouth (RM 253)	8	2.0	2.3	3.3
Keno Reservoir at Highway 66 Bridge (RM 234)	14	1.3	3.3	5.2
J.C. Boyle Reservoir (RM 224.8)	17	1.3	3.9	6.6
Copco Reservoir (RM 198.7)	25	0.6	6.2	11.2
Iron Gate Reservoir (RM 190.2)	25	3.0	7.5	13.8

[a] The average of the depths at which the Secchi disk disappears and the depth at which it reappears.

Measuring water clarity in river reaches requires a more complex sampling device designed to measure the water's turbidity, however, the instrument can be used in both lake and river conditions. A common unit of measure of turbidity is the nephelometric turbidity unit (NTU), which is a standardized measure of clarity based on light scattering in a water sample measured by the meter. The greater the amount of TSS in the water, the murkier it appears and the higher the measured turbidity.

Turbidity in project influenced reaches ranged from 0.9 to 184 NTUs (mean of the majority of the sites is below 10 NTUs) between 2002 and 2003 at many of the same locations as temperature and nutrient sampling; however, samples were not collected in the peaking reach. Table 3-32 shows the monthly mean turbidity values reported by PacifiCorp. The maximum reading of 184 NTUs was recorded in the epilimnion of Copco reservoir in May 2003.

Table 3-32. Mean turbidity (NTUs) in the Klamath River, 2002-2003. (Source: PacifiCorp, 2004a, as modified by staff)

Stations	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Link River[a]	10.1	8.5	8.1	12.9	11.0	11.0	12.0	11.8
Klamath Irrigation Project[b]		7.1	6.9	3.3	5.8	5.2	7.7	
Keno reservoir[c]	7.8	7.0	5.0	7.2	5.6	6.7	6.0	8.8
Klamath River below Keno dam	13.6	9.7	5.3	31.4	14.9	4.4	6.1	8.5
Klamath River above J.C. Boyle reservoir	13.4	9.5	6.0	7.3	11.9	3.4	4.9	8.4
J.C. Boyle reservoir at log boom (top 8 m)		8.9		6.5		2.8		
J.C. Boyle bypassed reach immediately below dam	14.4	10.0	6.0	7.6	4.8	2.9	3.1	7.8
J.C. Boyle bypassed reach (downstream end)	3.6	3.9	2.3	1.7	1.0	0.9	1.0	2.2
Klamath River above Shovel Creek (peaking reach)	11.4	7.5	4.8	6.8	2.1	2.0	3.1	3.8
Copco reservoir (top 8 m) near Copco		95.2		5.9		4.1		
Copco reservoir outflow	7.0	6.1	3.0	1.7	6.7	4.0	2.3	3.8
Iron Gate reservoir (top 9 m) near Hornbrook		7.1		2.1		2.3		
Iron Gate dam outflow	5.9	6.1	3.2	1.9	1.6	2.7	2.0	1.4

[a] Sampling points include: Link River near East Side powerhouse and Link River at mouth.

[b] Sampling points include: Lost River diversion canal at Klamath River, Klamath Straits drain pumping plant F, and Klamath Straits drain 200 feet downstream of pumping plant F.

[c] Sampling points include south-side bypass bridge, Miller Island boat ramp, upstream of Klamath Straits drain, between Klamath Straits drain and Keno dam, Keno Bridge (Highway 66), and Keno dam log boom.

TSS sampling results from 2003 (the only year sampled by PacifiCorp) indicate that TSS concentration ranged from 0 to 280 mg/L with the mean of Klamath River samples and reservoirs (including the metalimnion and hypolimnion of Copco and Iron Gate reservoir) of 7.9 mg/L. The maximum reading of 280 mg/L was recorded in the epilimnion of Copco reservoir in May, which corresponds to the same time frame when the maximum turbidity value was measured. The maximum TSS level recorded in the Copco outflow during the same month was 4.8 mg/L.

Toxics (Metals and Pesticides)

PacifiCorp conducted a screening level assessment of chemical contaminants in fish tissue samples taken from Upper Klamath Lake, Keno, J.C. Boyle, Copco, and Iron Gate reservoirs to assess potential threats to humans from the bioaccumulation of toxic substances (PacifiCorp, 2004h). The Water Board (2004) considers the sampling a screening level analysis only, which provides direction on additional fish tissue and/or sediment sampling, yet to be determined. Screening level values (based on EPA criteria) for protection of human health used in the study are for recreational fishers and subsistence fishers. The results of the fish tissue analysis represent an indication of the degree to which toxics may be present in project-influenced water and sediment. However, because in some cases fish are known to migrate substantial distances, if contaminants are found in fish tissue, they may have originated from habitat outside the project area.

All measured fish tissue concentrations for total mercury are well below the screening values for human health. Total mercury concentrations (ppb dry weight) ranged from 0.154 to 2.527. The screening value for wildlife exposure used by PacifiCorp was 2.27 ppb, dry weight. Concentrations measured in largemouth bass from Iron Gate reservoir (two composite samples, 2.299 and 2.527 ppb) and Copco reservoir (a single composite totaling 2.438 ppb) are slightly above the screening value for wildlife exposure. All other measured mercury values were below the screening value for wildlife.

Although arsenic was detected in several samples, no concentration exceeded the method reporting limit[42] of 0.3 ppm. Estimated values (those values between the method reporting limit and the method detection limit [0.1 ppm]) for arsenic concentration in samples of largemouth bass from J.C. Boyle, Copco, and Iron Gate reservoirs are below the toxicity screening value for recreational fishers, but equal or exceed the toxicity screening value for subsistence fishers, a level of 0.147 ppm. Estimated arsenic concentrations exceeded the subsistence fishers' toxicity screening value in fish taken from J.C. Boyle (0.19 ppm), Copco (0.19 ppm) and Iron Gate (0.17 ppm) reservoirs. Cadmium and selenium values are below all screening values in all samples. No screening values were available for other metals.

DDE and hexachlorobenzene were the only two pesticides or pesticide byproducts detected in the study and were detected below the human health screening values. Some of the fish tissue samples from Upper Klamath Lake and Keno, J.C. Boyle, Copco, and Iron Gate reservoirs exceeded the suggested wildlife screening value for total DDTs, of which DDE is a component. Concentrations of DDE ranged from between the method detection limit of 0.56 ppb and the reporting limit of 2.0 ppb and a maximum of 2.91 ppb reported in J.C. Boyle fish. Hexachlorobenzene was detected in only two samples and at levels below the method reporting limit.

PCBs were detected in all samples from all of project reservoirs. Total PCB concentrations were less than the screening value for recreational fishers in all samples. Total PCB concentrations exceed the screening value for subsistence fishers in black bullhead from Keno reservoir, and in largemouth bass from J.C. Boyle, Iron Gate, and Copco reservoirs (table 3-33). Total PCB concentrations in all the samples analyzed were less than the toxicity screening value for protection of wildlife.

Table 3-33. Total PCBs found in composite fish tissue samples in Project reservoirs, 2003. (Source: PacifiCorp, 2004h)

Site	Species	Total PCB (ppb)
Upper Klamath Lake	Black Bullhead	0.846
Upper Klamath Lake	Black Bullhead	2.015
Keno Reservoir	Black Bullhead	2.926
J.C. Boyle	Largemouth Bass	0.885
J.C. Boyle	Largemouth Bass	1.397
J.C. Boyle	Largemouth Bass	3.521
Copco Reservoir	Largemouth Bass	2.822
Copco Reservoir	Largemouth Bass	2.158
Iron Gate Reservoir	Largemouth Bass	6.574
Iron Gate Reservoir	Largemouth Bass	4.909

Notes: Method Detection Limit: Varies
Method Reporting Limit: 0.200 ppb
Screening Values: Recreational fishers (0.2 ppb); Subsistence fishers (2.45 ppb); Wildlife (100 ppb).

[42] The method detection limit is a statistically derived value, such that if an analyte is measured above this value the laboratory is 99 percent confident that the constituent is present at a value above this level. The method reporting limit is the limit at which the laboratory is confident about the measurement of the presence of the actual target analyte as determined within the sample matrix. Hence, values measured above the method detection limit but below the reporting detection limit are considered estimated values.

Aesthetics

Recreational user surveys conducted by PacifiCorp in the project area in 2001 contained information from some respondents on the public's perception of water quality. Thirty-eight percent of respondents in the project area said that water quality had detracted from their visit. Table 3-34 summarizes their responses.

Table 3-34. Perceived effect of water quality on recreational visits in the Klamath Hydroelectric Project study area (yes/no). (Source: PacifiCorp, 2004c)

Survey Question: Has water quality ever affected your visit to the Klamath River area?

Resource Area	Yes (percent)	No (percent)
Link River/Lake Ewauna/Keno Reservoir	32	68
J.C. Boyle Reservoir	39	61
Upper Klamath River/Hell's Corner Reach	61	39
Copco Reservoir	35	65
Iron Gate Reservoir	32	68
Study Area (Total)	38	62

Of those persons who felt that water quality detracted from their visit, the most commonly cited factor was algae or aquatic plants (respondents mentioned "algae, green stuff, muck, seaweed, moss, slime") and the attendant odor. Other factors that were mentioned included dead fish and turbidity. We discuss project-related aesthetics in more detail in section 3.3.7.1.3, *Aesthetic Resources*.

3.3.2.2 Environmental Effects

3.3.2.2.1 Water Quantity

Flow and Water Level Monitoring

PacifiCorp's proposed flow and water level regimes for project-influenced reaches and reservoirs and the recommendations of other entities for flow and water level management cover a variety of alternative measures for each project development. Because measures related to flow and water level management primarily pertain to protecting and enhancing aquatic and riparian habitat and recreational opportunities, we discuss the specific aspects of these measures in sections 3.3.3.2, *Aquatic Resources*, 3.3.4.2, *Terrestrial Resources*, and 3.3.6.2, *Recreational Resources*.

Regardless of the flow and reservoir and river levels that may be specified in a new license, the Commission would require a means to ensure compliance with such license conditions. We discuss means for monitoring flow and water levels for compliance purposes in the following section. Flow and water level gages are in place on many project-affected reaches and reservoirs (table 3-35).

exceptions (i.e., to accommodate routine maintenance of withdrawal systems of irrigators and other consumptive water users at Keno reservoir and extreme natural flow events) emphasize the importance of establishing a project operations coordination plan to ensure that operation of Keno development, if it remains under the Commission's jurisdiction, is consistent with the resource needs of those parties affected by its operation.

However, should the Commission determine that Keno development is not jurisdictional, PacifiCorp would still need to coordinate with Reclamation to ensure that flows released from Iron Gate development are consistent with Reclamation's BiOp for the protection of coho salmon (NMFS, 2002). Including Reclamation among the consulted entities during the development of a project operations coordination and monitoring plan would ensure that Reclamation's BiOp responsibilities are met by PacifiCorp's operation of the Klamath Hydroelectric Project, regardless of which specific developments are included in a new license for the project.

Oregon law, as interpreted by the Oregon Water Resources Department, determines water rights related to withdrawals from Upper Klamath Lake or Keno reservoir. Any water rights disputes that arise in Oregon between Reclamation and PacifiCorp would be for that department to resolve. The Commission would not attempt to resolve any issues regarding whether Klamath River water should be used for consumptive purposes by clients of the Klamath Irrigation Project or for hydroelectric purposes, if such use would conflict with established consumptive purposes.

3.3.2.2.2 Water Quality

Keno Reservoir Water Quality Management

Currently, water quality within Keno reservoir does not meet state objectives and a TMDL for the Klamath River is currently underway to address elevated pH, ammonia, nutrients, temperatures, chlorophyll *a*, and low DO concentrations. PacifiCorp states that poor quality of inputs and not project operations are the cause of poor water quality throughout the project area. The combination of hypereutrophic water in Upper Klamath Lake, coupled with the extensive amount of irrigated lands supported by the Klamath River, supply (at times), nutrient enriched water to Keno reservoir. During summer, conditions in Keno reservoir are ideal for algal blooms; elevated water temperatures, ample sunlight, and elevated nutrient levels from the greater percentage of enriched flow from Klamath Straits drain. The resultant algal blooms exacerbate water quality problems by affecting pH and DO, and may potentially include blooms of *Microcystis aeruginosa*, which produce a toxin that can be a threat to human health (discussed later in this section). Isolating the nutrient loading and the effect of Keno reservoir on water quality from Upper Klamath Lake, non-point sources, and internal loading has yet to be performed; however, the TMDL analysis currently underway will identify these loads.

In its license application, PacifiCorp did not include Keno development as part of its proposed Klamath Hydroelectric Project, and it stated that it does not believe Keno dam is rightly under the Commission's jurisdiction, due to its lack of influence on hydropower production. PacifiCorp states that it would continue to own the dam and appurtenant facilities; however, it would relinquish all hydropower responsibilities associated with the current license and would operate the development according to state of Oregon and Reclamation direction. Future jurisdictional authority could affect environmental stewardship, which could affect the water quality within Keno reservoir and downstream. We cannot pre-judge the Commission's determination of whether Keno development should continue to be under its jurisdiction. Therefore, we discuss the management of the reservoir and its role in water quality in the event that Keno development remains jurisdictional and a part of the project.

NMFS recommends that within 1 year of license issuance, PacifiCorp develop, in consultation with the agencies, a plan to manage Keno reservoir to improve water quality for fish habitat and meet water quality standards as measured immediately downstream of Keno dam. NMFS indicates that

possible measures that could be implemented under this plan include restoration of wetlands, treatment wetlands, mechanical aeration, and mechanical removal of algae. Should Reclamation develop such a plan that addresses water quality issues at Keno reservoir before, PacifiCorp would incorporate Reclamation's plan into its plan under NMFS' direction. FWS makes a similar recommendation to that of NMFS except as a precursor to the development of the plan, PacifiCorp would form and lead a regional team within 1 year of license issuance whose purpose would be to study and develop a Keno reservoir water quality plan. The plan would be filed with the Commission within 2 years of license issuance (rather than the 1 year specified by NMFS).

Oregon Water Resources recommends that PacifiCorp should be prepared to address Keno dam's share of TMDL effects on temperature, algae, and DO levels in Keno reservoir and the Klamath River. The Klamath Tribe recommends that PacifiCorp fund efforts to plan and implement measures to ameliorate water quality problems generated within Keno reservoir.

Our Analysis

There is no disputing that the quality of water entering, within, and leaving Keno reservoir is degraded. However, the degree to which the presence of Keno dam influences that water quality is not as clear. The dam and its impoundment affect water quality primarily by increasing surface area and hydraulic retention time. This increases water temperature and facilitates photosynthetic and microbial processes that can degrade water quality, by causing DO and pH fluctuations, and increases in concentrations of nitrogenous compounds, including ammonia and other nitrogen species. Because the rate of flow through the reservoir is largely a function of Reclamation's need to meet the 2002 BiOp flows below Iron Gate dam, it appears that water quality problems in Keno reservoir would be the same whether or not Keno dam remains part of the project. In that sense, it is the presence of the dam (and associated reservoir), rather than its specific use, that contributes to the observed water quality degradation.

Ongoing TMDL studies are designed to establish the appropriate load for various pollutants that the Klamath River can assimilate. If point sources of pollution are identified in the watershed that cause the allocated TMDL to be exceeded, corrective actions would be identified through the National Pollution Discharge Elimination System (NPDES) permit process. However, past precedent has not identified water that passes through a hydroelectric dam as representing a point source of pollution, and thus an NPDES permit is typically not required. In a proposed rule that would amend the Clean Water Act, issued on June 7, 2006, EPA seeks to clarify that water transfers are not subject to NPDES permit requirements because no addition of a pollutant occurs (Federal Register: June 7, 2006. Volume 71, Number 109, pages 32,887 to 32,895). The proposed rule specifically states that "the movement of water through a dam is not water transfer because the dam merely conveys water from one location to another within the same waterbody." EPA notes in its proposed rule that pollutants in transferred water would best be addressed at the source by the states through such mechanisms as water resource planning, land use regulations, and conditions of a water quality certification.

We agree with EPA that an effective approach to addressing water quality issues for water passing through hydroelectric dams is through water resource planning. Such planning is already occurring in the project area through the TMDL process and the ongoing development of Reclamation's Conservation Implementation Program for the Klamath Irrigation Project (the most recent version of the plan was issued in February 2006). If Keno development is determined to be jurisdictional, it would be appropriate for PacifiCorp to participate in cooperative water resource planning with the relevant agencies to identify feasible means for improving the quality of water released from Keno dam. We consider measures to reduce nutrient loading in Keno reservoir and in downstream project waters to be the most likely remedial measure that would come out of such cooperative planning. If nutrients are reduced, algal production would decrease and the resultant DO regime would be enhanced. By assessing feasible methods of reducing nutrient loading from Keno dam to downstream project waters, it may be possible to

curtail project-related effects at Copco and Iron Gate reservoirs. However, because the water quality at Keno reservoir influences water quality at all downstream project developments, development of a water quality management plan that encompasses all project waters, not just Keno reservoir, should be considered when specific remedial measures are developed. Consultation with appropriate resource agencies during the development of such a project-wide plan would ensure that water quality enhancement measures implemented by PacifiCorp would be developed with input from technical experts within resource agencies and coordinated with measures implemented by other parties pursuant to parallel water quality management initiatives. We discuss this approach later in this section under *Project-wide Water Quality Management*.

Water Temperature Remediation

Project operations have the potential to alter the temperature regime of affected waters. Keno and J.C. Boyle reservoirs generally do not stratify during the warmer months of the year (as indicated in section 3.3.2.1.2), and water entering and leaving the reservoir are approximately the same temperature. Lacking a hypolimnion, there are no controllable actions that can be taken to cool water released from either Keno or J.C. Boyle developments. Because Copco and Iron Gate reservoirs thermally stratify during the warmer months of the year (see figure 3-23), the potential exists that structural or operational changes at these projects could be used to reduce the temperature of water released downstream.

Figure 3-37 shows simulated water temperatures downstream of Iron Gate dam with and without the project, illustrating the effects of project operations on the downstream temperature regime. In general, the "without project scenario" has warmer temperatures in the spring and cooler temperatures in the summer and fall than the existing condition. This reflects the slower warming and slower cooling associated with the large water mass contained within the reservoir. Temperatures during much of July and August are usually higher than 20^0C with little variability. Figure 3-37 is based on 2002 data and represents a dry year resulting in more extreme summer temperatures. Modeling results for other years between 2000 and 2004 can be found in PacifiCorp's response to AIR AR-2 filed by letter dated October 14, 2005, which exhibit similar, albeit less extreme, temperature trends. As discussed in section 3.3.2.1, PacifiCorp regularly recorded average daily water temperatures below Iron Gate dam of more than 20°C in June, July, and August between 2000 and 2004. In this section, we discuss the effects of various operational procedures, potential structural modifications, and monitoring. We discuss the relationship between temperatures and aquatic resource needs in section 3.3.3.2, *Aquatic Resources*.

In its license application, PacifiCorp originally proposed to evaluate the feasibility and effectiveness of a low-level release of cooler hypolimnetic water from Iron Gate and Copco reservoirs during the summer to provide some cooling downstream of the project. We asked PacifiCorp to conduct this analysis in our AIR dated February 17, 2005 (AR-1). In its response, filed by letter dated August 1, 2005, PacifiCorp indicated that none of the preliminary facility or operational modifications they considered would result in any substantial relief to the warm summer and fall temperatures downstream of Iron Gate dam.

The Forest Service recommends that the temperature of water released from Copco and Iron Gate dams should be managed to compensate for project cooling effects in spring and warming effects in late summer and early fall. Studies to determine a preferred design of intake structures and an outflow schedule would be conducted, and an effective combination of structure(s) and release operations should be required that would result in the greatest change in degree-days.

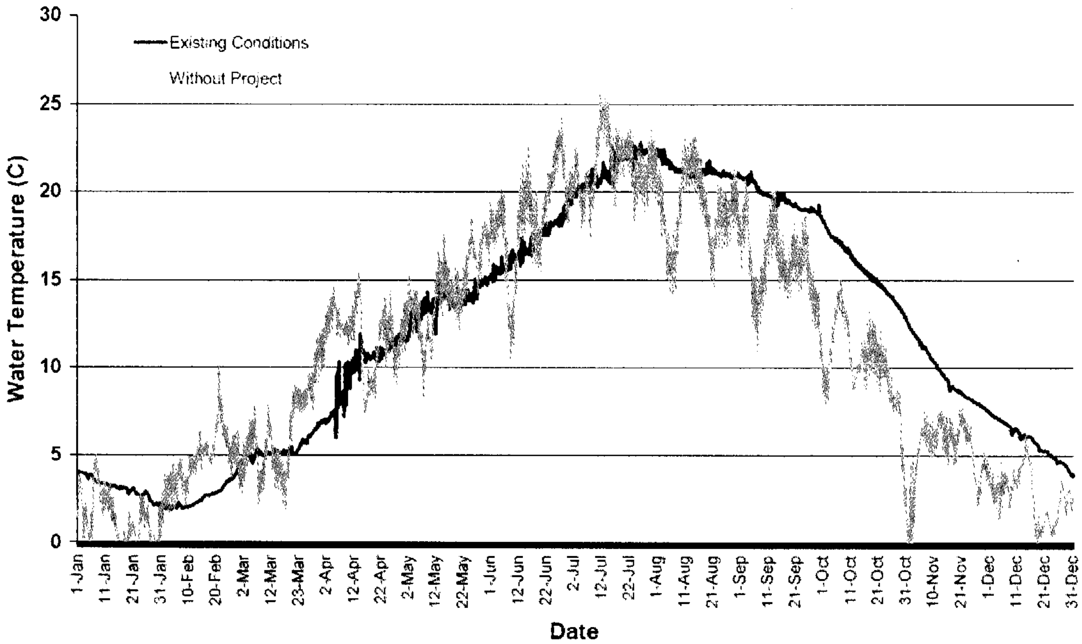


Figure 3-37. Simulated hourly water temperature below Iron Gate dam (RM 190.5) based on 2002 (considered a dry year) for existing conditions compared to hypothetical conditions without the existing Klamath Hydroelectric Project. (Source: PacifiCorp, response to AIR-AR-2, dated October 2005)

NMFS recommends that within 1 year of license issuance, PacifiCorp file a temperature control device feasibility and implementation plan developed in consultation with the resource agencies. Feasibility would be conducted by an independent third party approved by the agencies to determine the potential effectiveness of a temperature control device at Copco No. 1 and Iron Gate dams to improve habitat resources for anadromous salmonids downstream of Iron Gate dam. The goal of the plan would be the development and implementation of a comprehensive management plan to improve water temperature conditions downstream of Copco No. 1 and Iron Gate dams. Methods and results would be reviewed by the agencies, and if the results of the feasibility study are favorable, PacifiCorp would implement the recommended temperature control measures. The plan would fully model, compare, and evaluate a variety of technologies, including but not limited to construction and operation of a multi-port selective withdrawal structure. It would also include an assessment of effectiveness, cost, and potential effects. FWS makes a similar recommendation, however it also recommends the study should include an uncertainty analysis to quantify model performance for all years simulated, establish a realistic target water temperature schedule, and assess the effect of temperature control options on Iron Gate Hatchery operations.

Siskiyou County recommends "…appropriate terms and conditions that result in the aeration and management of cold water in the project reservoirs if these practices have appropriate benefits." Conservation Groups recommend that PacifiCorp operate the project in a run-of-river mode such that the amount of water entering an impoundment is equal to the sum of water passed over the dam, through fish passage facilities, and through the turbines at any given point in time at every relevant facility structure to enhance water temperature. Conservation Groups also recommend that PacifiCorp install adequate temperature monitoring devices and develop an effectiveness monitoring plan that includes the Klamath River downstream of Iron Gate dam to the confluence of the Shasta River to track compliance with water temperature objectives and force adjustments if temperature targets are not met. Conservation Groups

also recommend that in the absence of project decommissioning, PacifiCorp should pass sufficient water through the J.C. Boyle and Copco No. 2 bypassed reaches to minimize thermal effects from warming throughout each reach.

Our Analysis

We have seen no evidence that operation of the project in a run-of-river mode as recommended by the Conservation Groups would result in downstream temperatures being more suitable for salmonids. Operating J.C. Boyle in a run-of-river mode is not likely to induce measurable differences in temperature in the peaking reach because of the relatively small volume of the reservoir and lack of substantial stratification. Operating Copco No. 1 and No. 2, and Iron Gate developments in a run-of-river mode would result in the continuous seasonal release of relatively warm epilimnetic water from Copco and Iron Gate reservoirs, resulting in little expected change from the existing temperature regime.

The Conservation Group's desire to minimize thermal effects from warming in the J.C. Boyle bypassed reach would best be achieved by releasing no flow to the bypassed reach, not more flow. The more than 200 cfs of springwater accretion in the bypassed reach ensures optimal thermal conditions for salmonids during the warm months of the year and any additional flow released from the dam would serve to further warm the bypassed reach water. We consider it inappropriate to manage the J.C. Boyle bypassed reach solely to reduce water temperature. As discussed in section 3.3.3.2.1, *Aquatic Resources, Instream Flows*, both temperature and physical habitat (depth, velocity, and substrate) should be assessed when determining an appropriate flow regime for any stream reach.

Similarly, passing an alternative water flow through the Copco No. 2 bypassed reach, as recommended by the Conservation Groups, would likely have little effect on thermal regime. The bypassed reach is relatively short and much of it is shaded by encroaching riparian vegetation which, given the relatively low volume of flow currently passing through the reach (about 10 cfs), likely maintains water temperatures. Releasing additional flow from Copco No. 2 dam would pass warm water (originating from the epilimnion of Copco reservoir and passing through Copco No. 1 powerhouse) to the bypassed reach, most likely resulting in little change to current conditions. As indicated in the following paragraph, releasing cooler hypolimnetic water through a valve or gate at the base of the dam, may be possible, but such water would also be low in DO (see figure 3-28). Striking a balance between cooler temperature and DO that is likely to be acceptable for salmonids and resident fish in the bypassed reach would be difficult. Consideration of temperature, DO, and physical habitat collectively should be used to select an appropriate flow regime for the Copco No. 2 bypassed reach (see section 3.3.3.2.1, *Aquatic Resources, Instream Flows*).

PacifiCorp modeling (response to AIR AR-2, October 17, 2005) of existing conditions compared to the without project scenario indicates that the project can have a noticeable effect on temperatures as far downstream as the confluence of the Scott River, 47 miles downstream of Iron Gate dam. The magnitude, downstream extent, and duration of project effect on temperatures is variable and influenced by numerous factors such as, but not limited to, water year type; climatic and meteorological conditions, and season. Differences in temperature between the modeled existing condition and the without project scenario are most noticeable during the summer and early fall months as the thermal mass of the reservoirs alter the downstream temperature regime. Modeling results indicate that effects of the project on temperature are difficult to discern by the confluence with the Salmon River, about 124 miles downstream of Iron Gate dam, which indicates that the likely downstream limit of project effects on water temperature is between the confluence of the Scott and Salmon rivers.

Thermal stratification and the associated cool water in the hypolimnion during warmer times of the year in Copco and Iron Gate reservoir provide the potential to allow selective withdrawals of water from depths within the reservoir to provide relief from peak summer temperatures downstream of Iron Gate. PacifiCorp analyzed the hypothetical release of hypolimnetic water from both Copco and Iron Gate

reservoirs using the CE-QUAL-W2 modeling system which has since been incorporated by the EPA into their technical analysis of the forthcoming Klamath River TMDL, giving the model a high level of credibility. PacifiCorp estimates the maximum useable cold water volume in Copco reservoir to be about 3,100 acre-feet and 4,800 acre-feet at less than 14°C and 16°C, respectively. This maximum volume of cold water typically occurs around September 1, which is when it would most likely be needed to provide downstream temperature relief for migrating salmon. PacifiCorp's modeling results show that the duration of hypolimnetic releases from that storage would last about 1.8 days at 1,000 cfs. It may be possible to extend this release period by a small amount by reducing the release volume to less than 1,000 cfs. However, if inflow to Copco reservoir exceeds the amount released from near the base of Copco No. 1 dam, the reservoir would fill and spill, or epilimnetic water would need to be released through the powerhouse; both actions would release warm water into Copco No. 2 reservoir and negate the temperature benefits of the cool, hypolimnetic releases. As table 3-19 shows, the average flow at the Copco No. 1 powerhouse is 702 cfs in July, 804 cfs in August, and 974 cfs in September, which are the months when temperature relief would most likely to be needed. We independently reviewed PacifiCorp's area-capacity curves and vertical temperature profiles for Copco reservoir and concur with PacifiCorp's assessment of the relatively limited coldwater release capabilities at Copco No. 1 dam. To achieve releases of the magnitude and duration specified by PacifiCorp, releases would need to be made from a valve or gate near the base of the dam and water used in any such releases could not be used to generate electricity. PacifiCorp refurbished these low level outlets in 2005 to comply with state of California dam safety requirements (PacifiCorp, 2005i). As we note in the previous paragraph, any such hypolimnetic flow release would likely be very low in DO.

PacifiCorp's modeling indicates that at Iron Gate reservoir, the maximum volume of cold water (8°C or less) during the summer is about 8,000 to 10,000 acre-feet. If all of this cold water were passed through a point near the base of them dam at a release rate of 1,000 cfs, this cold water pool would last about 5 days. Our independent review of PacifiCorp's area-capacity curves and vertical temperature profiles for Iron Gate reservoir confirms PacifiCorp's assessment of the size of the cold water pool. We also estimate the approximate volume of the cold water pool available at Iron Gate reservoir in the hypolimnion that would be at or 15°C, to be about 20,000 acre-feet. A release of about 1,000 cfs from near the base of the dam could be sustained for about 10 days. PacifiCorp refurbished these low level outlets in 2005 to comply with state of California dam safety requirements (PacifiCorp, 2005i). As with hypolimnetic releases at Copco dam, the DO of water released from near the bottom of Iron Gate reservoir would generally be very low.

PacifiCorp's modeling efforts of selective withdrawal alternatives for Copco and Iron Gate show the cold water pool within the reservoirs could be used for modifying temperatures below the dam; however effects would be short term and would not affect the entire length of river below Iron Gate dam to the ocean. Our review of PacifiCorp's modeling efforts leads us to conclude that it is a valid tool to help understand the limitations of releases of cold, hypolimnetic water from Copco and Iron Gate reservoirs in relation to the temperature regime of project waters. If releases from Iron Gate dam are managed to sustain decreased temperatures for the longest duration, hourly temperatures would be reduced by about 1.1°C on average, with a maximum decrease of 1.8°C, for a period of up to 1 -1/2 months in late summer and early fall. Modeling of selective withdrawals from Iron Gate alone designed to maximize the decrease in downstream water temperatures showed promise but the benefits end within 2 weeks, as the cold water pool is depleted. Temperature benefits are reduced at Seiad Valley, with almost no benefit below Clear Creek (about 90 miles below Iron Gate) leaving the lower 100 miles of river unaffected. PacifiCorp's modeling results show that selective withdrawals could reduce temperatures below existing conditions by a maximum reduction of 10°C, which would last for about a day midway through the withdrawal period. As the distance downstream from Iron Gate dam increases, observed and modeled temperatures show greater variability as the river becomes more responsive to changes in meteorological conditions. The magnitude of the benefit is related to the hydrological conditions, as temperatures during drier years with less tributary inflow are more sensitive to releases

from Iron Gate dam because they make up a greater percentage of the flow, whereas during wet years the opposite would be true. Selective withdrawal modeling scenarios designed to prolong greater temperature differences by incorporating Copco reservoir into a coordinated effort to lower water temperature downstream of Iron Gate dam showed negligible benefits.

Sustained temperature relief of more than 2 weeks to the Klamath River via releases from Iron Gate dam is not feasible. However the cold water pool in Iron Gate has some potential to cool downstream temperatures on a short term basis, and could be considered for extreme circumstances should environmental conditions trigger such a need (e.g., when large numbers of juvenile salmonids are present in the river under extreme temperature stress). Depletion of the cold water pool to reduce warm temperatures below Iron Gate dam would also likely decrease the DO concentration downstream of Iron Gate dam, through the release of oxygen depleted water from the hypolimnion, as previously noted. In addition, the sole water supply for Iron Gate Hatchery withdraws cold water from the deeper water of Iron Gate reservoir, and depleting or exhausting this cold water pool during the summer would likely seriously impair hatchery operations during any year that such hypolimnetic releases occur (see section 3.3.3.2.6, *Aquatic Resources, Iron Gate Hatchery Operations*). Development of a temperature control plan would provide the framework necessary to address cold water withdrawals while integrating water quality monitoring and aquatic resource needs. Addressing the feasibility of renovating the existing Iron Gate dam diversion tunnel to make controlled hypolimnetic releases or installing alternative hypolimnetic release valves or gates that could be activated in emergency circumstances to provide short-term downstream temperature relief could be included in a temperature control plan. In addition, conducting a feasibility study to assess alternative or supplemental Iron Gate Hatchery water supply options that could provide temporary cool water supplies to the hatchery (during any use of hypolimnetic water under emergency circumstances) would provide a basis to determine the overall feasibility of an emergency coolwater flow augmentation program. Alternative supply options to be studied could include: groundwater source availability, piping water from coldwater tributaries, or a combination of several options. NMFS and FWS recommendations for additional, third party, selective withdrawal modeling for the purposes of comparing and evaluating a variety of technologies would be unnecessary based on the limited amount of cold water storage available within Iron Gate reservoir and the current capability to release available cold water, if needed, at Iron Gate dam. An emergency water release plan that specifies environmental target temperatures by season and environmental triggers could be used to signal the release of cool water from storage in Iron Gate reservoir to provide short term benefits to anadromous fish experiencing temperature stress and may improve relief through critical early fall temperature extremes.

Addressing operational measures to be considered to increase the temperature of late spring releases from Iron Gate dam, including spills, to reduce the thermal lag in the Klamath River downstream could assist fall Chinook growth and early emigration (discussed in section 3.3.3.2.5, *Aquatic Resources, Disease Management*). Initially this option could rely on existing facilities to achieve the benefits of limited short-term temperature relief. An adaptive management approach would allow the most flexibility in achieving temperature objectives while incorporating monitoring results to promote the appropriate conditions for aquatic resources. Details of such an approach could be specified in a temperature management plan.

Dissolved Oxygen Remediation

PacifiCorp's sampling and modeling efforts under "existing conditions" and "without project" scenarios show that operation of the project has an effect on the downstream DO regime. Specifically, the results show that project operations under existing conditions result in reduced DO releases, often below California's numerical objectives (listed previously in table 3-24), downstream of Iron Gate dam from late spring, through the summer and fall. The modeling results indicate that the project influences DO concentrations at least as far downstream as the confluence of the Klamath and Shasta rivers. Distinguishing project-related influences from non-project influences on the DO regime further

downstream is difficult using either modeling or field measurements because of the number of variables that influence DO (e.g., degree of turbulence, time of year, time of day, influences of tributary inflow, and non-project-related BOD and SOD). Figure 3-38 shows DO concentrations below Iron Gate dam that are representative of dry, low flow conditions. Under the "without project" scenario, DO concentrations could drop below the state objectives of 8 mg/L; however, the duration of these conditions would be short lived compared to the modeled existing conditions. Modeling results for other years illustrate similar trends, with increased variability. These results can be found in PacifiCorp's response to AIR AR-2 dated October 17, 2005.

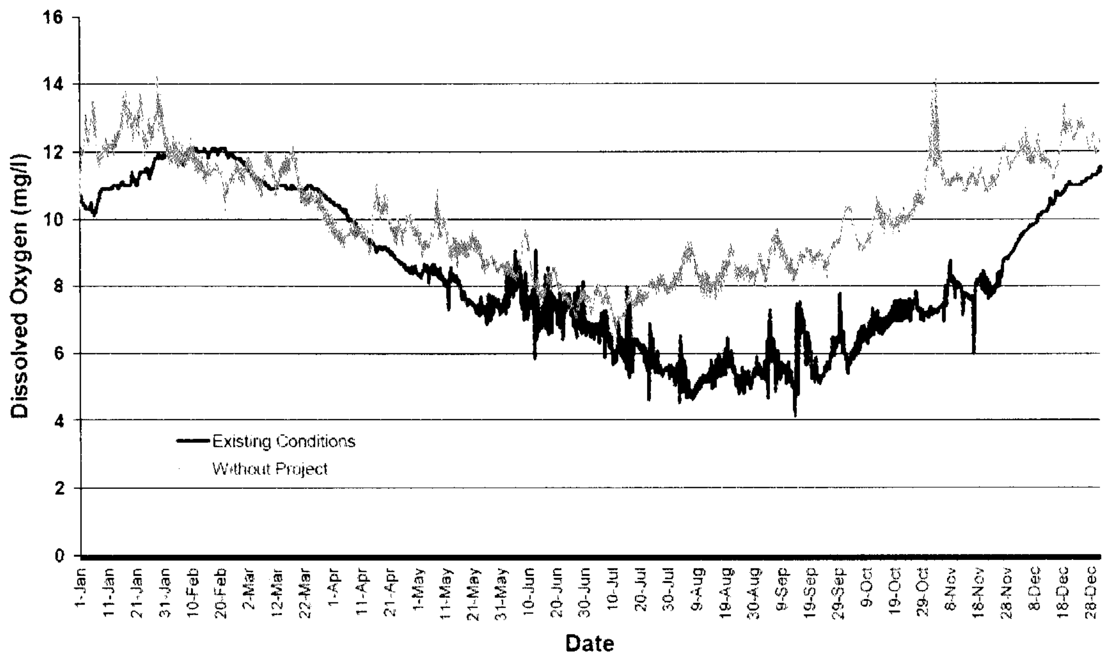


Figure 3-38. Simulated hourly DO levels below Iron Gate dam based on the year 2002 (a dry year) for existing conditions compared to hypothetical conditions without the Klamath Hydroelectric Project. (Source: PacifiCorp, response to AIR AR-2, dated October 17, 2005)

To address the reduced DO levels below Iron Gate dam, PacifiCorp proposes to install an oxygen diffuser system in Iron Gate reservoir to assist with compliance with the state water quality objective for DO downstream of the project (PacifiCorp, 2005, response to AIR AR-1 part [b]). The diffuser system would include a single diffuser line about 4,000 feet long, located in the deepest portion of the reservoir, designed to supply oxygen to the hypolimnion. The diffuser system would be operated seasonally each year beginning in the spring, as bottom water DO levels start to drop, and continue until reservoir turnover in the fall. Should conditions require, additional oxygen would be placed in the turbine water flow using three shorter diffusers in front of the intake tower. PacifiCorp proposes to monitor DO levels in the tailrace to provide guidance on potential adjustments of oxygen injection. As a separate, but related measure, PacifiCorp also proposes to develop and implement comprehensive water quality management plans for the reservoirs of the proposed project which would include an evaluation of the effectiveness and feasibility of several technologies, including further evaluation of hypolimnetic oxygenation and epilimnetic or surface aeration and circulation. We discuss PacifiCorp's proposed water quality management plans later in *Project-wide Water Quality Management*.

NMFS recommends that, within 1 year of license issuance, PacifiCorp file a DO enhancement plan, developed in consultation with the resource agencies, for the project reaches and Klamath River downstream of Iron Gate dam to improve habitat resources for anadromous salmonids. The goal of the plan would be the development and implementation of a comprehensive management plan to enhance DO downstream of Iron Gate dam that would include (1) measures to meet salmonid requirements for the geographic extent of the project DO effect; (2) further study of PacifiCorp's proposal to install a hypolimnetic oxygenation system in Iron Gate reservoir to demonstrate downstream effectiveness and evaluate the potential for adverse effects on nutrient levels and thermal stratification; and (3) provisions to fully model, compare, and evaluate a variety of technologies, including but not limited to liquid oxygen injection (intake and draft tube), gaseous oxygen injection (intake and draft tube), construction and operation of a multi-port selective withdrawal structure, and turbine venting, and include an assessment of effectiveness, cost, and potential effects.

FWS recommends that PacifiCorp's proposal to install a hypolimnetic oxygenation system at Iron Gate reservoir be studied further to demonstrate downstream effectiveness and the potential for adverse effects on nutrient levels and thermal stratification. PacifiCorp would also study the potential effectiveness of a hypolimnetic oxygenation system at Copco No. 2, and J.C. Boyle dams and the potential for adverse effects on nutrient levels and thermal stratification. These studies would provide recommendations to control DO content of reservoirs and released waters from reservoirs to meet salmonid fish requirements for the geographic extent of project DO effects without exacerbating algal blooms or disrupting reservoir thermal stratification. As part of these studies, the role of nutrient input and cycling would also be studied and remedies to the problems of hyper-eutrophication proposed. PacifiCorp would develop and submit to the Commission for approval a DO enhancement plan that would specify measures proposed for implementation, based on these studies. The studies and plan would be developed in consultation with the agencies and be fully implemented within 3 years of license issuance.

The Forest Service recommends that the DO level of water released from Iron Gate dam should be controlled to meet salmonid fish requirements for the geographic extent of project DO effect, without exacerbating algal blooms. The PacifiCorp-preferred design (hypolimnetic oxygen diffuser) would be studied further to demonstrate downstream extent of effectiveness.

Siskiyou County states they are in favor of appropriate terms and conditions that result in aeration of water in the reservoirs, if these practices have appropriate benefits. Conservation Groups recommend that PacifiCorp operate the project in a run-of-river mode to enhance DO, such that the amount of water entering an impoundment is equal to the sum of water passed over the dam, through fish passage facilities, and through the turbines at any given point in time, at every relevant facility structure.

Our Analysis

We have seen no evidence that operation of the project in run-of-river mode, as recommended by the Conservation Groups, would increase the DO in the outflows of any of the project reservoirs. Low DO concentrations observed in project reservoirs are likely the result of high BOD in the water column, stemming from high levels of organic material, rather than the peaking and re-regulating operations of the dams. Operating the project in run-of-river mode would continue to draw water from the existing intakes and comparable depths and would result in DO levels that are similar to levels released from project structures under existing conditions.

Currently, DO concentrations measured at flows that range from 370 to 2,400 cfs in the J.C. Boyle peaking reach meet applicable state objectives. When the J.C. Boyle powerhouse is operating in peaking mode, generation flows are released only during the day. Typically, summer DO concentrations are higher in a reservoir during the day, when photosynthesis produces oxygen, than at night, when respiration depletes oxygen. If J.C. Boyle were to operate in a run-of-river mode during the summer, generation flow releases from the powerhouse would be relatively constant over a 24-hour period.

Releases during the daytime would contain higher concentrations of DO, and the increase in concentrations in the peaking reach via natural aeration would be limited. The resultant increased flow at night would create more favorable conditions for a re-aeration from the turbulence in the peaking reach because oxygen dissolves more readily in water with low DO. It is uncertain whether increased DO uptake at night in the peaking reach would influence the DO regime in downstream Copco reservoir.

Our review of available DO data and modeling results from downstream of Iron Gate dam indicates that during the warmer months of the year, project operations results in DO that does not meet applicable water quality objectives. Therefore, measures to enhance DO downstream of Iron Gate should be implemented. Implementation of PacifiCorp's proposal to inject oxygen into the bottom waters of Iron Gate reservoir during times of low DO concentrations would increase DO concentrations within the reservoir; however, based on our review of PacifiCorp's assumptions of oxygenation efficiency and the measured DO concentrations at a depth of 40 feet (the powerhouse intake depth) during the summer and fall months, we conclude that the proposed diffuser technology may not be sufficient to meet state water quality objectives for DO downstream of the dam. The average DO concentration in Iron Gate reservoir from July to October at a depth of 40 feet was between 1.1 and 4.9 mg/L during 2000 to 2004 and the oxygen delivery capacity of the conceptual design is based on providing 1 to 3 mg/L of DO uptake.

In addition to our concerns regarding effectiveness, implementation of a hypolimnetic oxygenation system, although designed to enhance DO concentrations, may produce undesirable or unanticipated secondary effects. PacifiCorp's hypolimnetic oxygenation modeling (PacifiCorp, 2005i) predicts there would be a slight rise in outflow temperatures in August and September when forced oxygenation or aeration is applied. PacifiCorp credited this to a complex relationship with algae shading; however, several agencies question the ability of the model to capture the complex interactions created by adding oxygen to the bottom of such a eutrophic reservoir. Wells (2004) points out that it is difficult to account for the complex relationship of nutrients, algae, and DO concentrations in models that are currently available. However, he suggests that without factoring such considerations into the modeling, the results may not predict actual DO and temperature outcomes. Although we agree that modeling temperature and DO in stratified eutrophic reservoirs may have drawbacks, it is the best available tool for predicting outcomes of various alternatives, and general trends shown by the model results can serve a valuable purpose with regard to the potential results of implementing environmental measures. However, the uncertainty of modeling results emphasizes the importance of verifying actual environmental responses by data collection in the field.

Turbulence created as oxygen rises through the water column would also likely alter the location of the thermocline, or possibly eliminate it. If this occurs, the potential for cool, hypolimnetic releases to lower the water temperature downstream of Iron Gate dam would be reduced. PacifiCorp's modeling results show that conditions with higher DO concentrations exhibit greater concentrations of inorganic nutrients (e.g., nitrate-nitrite) compared to nutrients bound to organic molecules, which may exacerbate algae blooms because algae can more readily assimilate inorganic nutrients. The modeling results showed oxygenation of the reservoir slightly decreased ammonia, noticeably decreased orthophosphate, and substantially increased nitrate-nitrite in the outflow between mid-July and mid-October. The ammonia and orthophosphate results are consistent with monitoring results taken before and after installation of a hypolimnetic oxygenation system in Comanche reservoir in California (Beutel, 2005). Chlorophyll *a* concentrations in Comanche reservoir decreased to about a quarter of that measured prior to hypolimnetic oxygenation, which is the opposite of what PacifiCorp's model predicts.

Increased amounts of inorganic nitrogen released downstream could affect the growth of attached algae in the river below the dam because the Klamath is nitrogen limited, as described in our discussion of the affected environment (see section 3.3.2.1.2). This could have other unwanted effects, such as increasing suitable habitat for the intermediate host of the salmonid pathogen *C. shasta*, discussed in the following subsection, *Monitoring and Control of Algae that Pose a Risk to Fish, Wildlife, and Public Health*. In light of our analysis, additional study of hypolimnetic oxygenation is warranted prior to

implementing such a program in order to determine if the expected environmental benefits would outweigh any adverse environmental effects.

Oxygen or air injection into the turbines would increase DO levels in project outflows without the associated potential consequences of a hypolimnetic oxygenation system. The need for DO enhancement downstream of Iron Gate dam is immediate, especially during dry or critically dry years. Turbine air venting, which PacifiCorp's consultant estimates could increase DO in the Iron Gate dam tailwaters by at least 2.2 to 2.7 mg/L, depending on the configuration (Mobley, 2005), could be implemented with relatively minor adjustments to the turbine headcover or draft tube. Implementing turbine venting would provide some short-term relief during periods of low DO, enabling alternative long-term DO enhancement solutions to be further evaluated (in the context of remedial measures) to address other water quality issues in project waters. Depending on the results of DO monitoring in the tailwaters, turbine venting may also represent a viable long-term solution to the existing DO problem. Monitoring DO in the tailrace as well as in the reservoir adjacent to the Iron Gate powerhouse would provide data regarding the effectiveness of this approach, whether modifications to the venting system are needed, and whether supplemental or alternative DO enhancement measures should be considered.

Improving the DO concentration of the upstream hydro releases could further assist PacifiCorp in meeting DO objectives downstream of Iron Gate dam. As a supplement to air or oxygen injection at Iron Gate, injection could also be provided at Copco No. 1 or No. 2 powerhouse turbines which would increase DO concentrations of water entering Iron Gate reservoir. Flows from Copco No. 2 powerhouse would be discharged to the epilimnion of Iron Gate reservoir and the density of the relatively warm, oxygenated water would not likely be great enough to penetrate the thermocline. This would shorten the residence time of this water as it passes through Iron Gate reservoir because the oxygenated inflow would pass over the denser water to the intake of Iron Gate powerhouse. As figure 3-24 shows, water that flows through the powerhouse is primarily drawn from a location near the surface. Figure 3-28 (DO profiles) shows that, during the summer, the top few meters have high concentrations of DO while concentrations drop off substantially after 5 meters. Increasing the DO concentration in the top 10 meters of Iron Gate reservoir should translate to enhanced DO concentrations in the Klamath River downstream of Iron Gate dam. DO monitoring in Copco No. 2 and Iron Gate reservoirs coupled with DO monitoring in the Iron Gate tailwaters would document the effectiveness of such an approach, if implemented.

Spillage from project dams would increase downstream DO and may be appropriate for consideration in a comprehensive DO enhancement plan. This method could be used at times when spills would not result in inappropriate increases in water temperature downstream of Iron Gate dam, such as in May or June; however, DO concentrations at this time of year are typically above state objectives. Spillage at Copco No. 2 dam during certain times would increase DO of water entering Iron Gate reservoir through the relatively steep Copco No. 2 bypassed reach by using natural aeration from turbulence. This approach could be triggered by target DO concentrations in Iron Gate reservoir or downstream and may be more effective than direct air or oxygen injection at Copco No. 2 powerhouse. Using spillage to increase DO downstream of Iron Gate could also be achieved without the potential negative effects on nutrients and temperature that could occur with hypolimnetic oxygenation.

Monitoring DO concentrations in the outflows of Iron Gate near the USGS gage would assist in the management of an air or oxygen injection system at the turbines or within the waters of the reservoir while providing data for compliance monitoring. Incorporation of additional water quality parameters and locations would further assist PacifiCorp and appropriate parties in evaluating the effectiveness of any implemented measure and its effects on water in the reservoir. Development of additional studies to increase the understanding of relationships between enhanced DO concentrations and nutrient and algae dynamics, as recommended by NMFS, FWS, and FS, are actions similar to measures that would occur in PacifiCorp's proposed reservoir management plans, discussed later under *Project-wide Water Quality Management.* Distribution of PacifiCorp's plans to appropriate agencies for review and comment prior to filing with the Commission would ensure that the study plans address the best available technologies,

resources, and monitoring techniques to ensure the chosen strategy would improve water quality. Implementation of air or oxygen injection systems at Copco No. 1 and 2 powerhouses, spillage at dams, or hypolimnetic oxygenation, if appropriate, could be initiated over time under an adaptive tiered approach, based on feasibility analysis and monitoring. A reasonable time frame for completing this adaptive approach would be 5 years (during which one or more additional DO enhancement measure may be implemented, if needed).

Monitoring and Control of Algae that Pose a Risk to Fish, Wildlife, and Public Health

During summer 2005 (Kann et al., 2006), and 2006 (Water Board, 2006), Copco and Iron Gate reservoirs experienced substantial and sustained blooms of the blue-green algae, *Microcystis aeruginosa*, and accompanying high levels of microcystin a toxin often produced by this algae. These algal blooms were detected starting in mid-July and lasted through most of October. During much of this period, cell density levels of *Microcystis aeruginosa* and microcystin toxin concentrations exceeded threshold levels identified by the World Health Organization as posing a Moderate Probability of Adverse Health Effects. There are no federal or California regulatory guidelines for cyanobacteria and their toxins. Although the toxic algae *Microcystis aeruginosa* has been known to occur regularly in Upper Klamath Lake (Gilroy et al., 2000), where it may degrade the quality of commercially harvested populations of the blue-green algae, *Aphanizomenon flos-aquae*, and as far as 125 miles downstream of the project reservoirs (Kann et al., 2006), this was the first time the extent of the blooms and their toxicity, at locations other than Upper Klamath Lake, had been documented and health advisories issued by public agencies (Water Board) for project waters.

In addition to the toxic algae, the fish pathogens *C. shasta* and *Parvicapsula minibicornis* occur throughout the Klamath Basin and are a source of mortality to migrating salmonids throughout the Klamath River. PacifiCorp's investigation into *C. shasta* and its intermediate polychaete host *Manayunkia speciosa (M. speciosa)* indicates that habitat for the polychaete is available in areas of the project, primarily in free-flowing stretches of the river and riverine segments of the reservoirs (PacifiCorp, 2004f). The study of *C. shasta* is complicated by the fact that the pathogen changes form and apparently function, and has multiple hosts (juvenile fish and a polychaete alternate host) (Stocking and Bartholomew, 2004). Benthic sampling efforts within the Klamath River discovered the highest densities of the polychaete worms were always found within dense populations of the attached algae *Cladophora* (PacifiCorp, 2004f). One hypothesis for the high incidence of *C. shasta* in the Klamath River is that the polychaete populations have increased as a result of an increase in available habitat, most notably *Cladophora* (Stocking and Bartholomew, 2004). Bartholomew and Cone (2006) recently found the fish pathogen *P. minibicornis* requires the same worm host as *C. shasta*, thus, conditions that support *Cladophora* growth could enhance the prevalence of both fish pathogens. *Cladophora* populations, as well as other populations of aquatic vegetation, increase when nutrients enrich areas of suitable habitat. Whether or not the project contributes to nutrient enrichment is a complex issue. We discuss the effects of *C. shasta* and *P. minibicornis* on salmonids in section 3.3.3.2.5, *Aquatic Resources, Disease Management.*

PacifiCorp proposes to implement Reservoir Management Plans aimed at reducing algae concentrations, increasing dissolved oxygen, and improving pH. The Reservoir Management Plans would be designed to evaluate the effectiveness and feasibility of several technologies and measures (specifically hypolimnetic oxygenation, epilimnetic or surface aeration and/or circulation, and copper sulphate algaecide treatment) for more effectively controlling water quality conditions in the reservoirs. Although relevant to the control of algae in project waters, we discuss this measure, as well as recommendations of others that could reduce nutrient loading and thus control algal blooms, in the following section, *Project-wide Water Quality Management.*

FWS recommends that PacifiCorp develop a monitoring program, in consultation with other agencies, to assess the risk of toxic cyanobacteria blooms in Iron Gate and Copco reservoirs on fish health

and the environmental factors that lead to such blooms and their adverse effects on fish. A plan would be developed, in consultation with the agencies, and implemented to reduce the risk of cyanobacteria blooms on fish.

Siskiyou County recommends that PacifiCorp provide for the removal of those species of blue-green algae that are a hazard and risk to health and safety of people and animals during the summer period when algae blooms occur. Conservation Groups recommend that PacifiCorp monitor for *Microcystis aeruginosa* in Copco and Iron Gate reservoirs and locations on the Klamath River affected in past years, downstream to the estuary, and at appropriate trigger points take appropriate actions (consult with public health authorities and public notification).

Our Analysis

Microcystis aeruginosa has appeared regularly in Upper Klamath Lake and the extent of the blooms and toxicity documented in 2005 indicates that the algae has dispersed downstream and may have bloomed in project reservoirs prior to last year's documentation. However, in the absence of a structured monitoring program, any previous occurrence of toxic algal blooms would have been undetected. The persistence of *Microcystis* in Upper Klamath Lake suggests that there would be continuing availability of algal cells to seed *Microcystis* blooms under favorable conditions in all project reservoirs. Commission regulations specify that hydropower project licensees provide reasonable public access to project lands and waters, as long as public safety is protected. The public currently enjoys water-based recreational activities, such as swimming, angling, and boating at facilities at all project reservoirs. The toxin produced by *Microcystis* represents a threat to public safety. A structured monitoring program, developed in consultation with resource and public health agencies, based on known life history characteristics of *Microcystis,* would enable monitoring to occur and, if necessary, public health advisory notices to be posted when microcystin levels in the water reach threshold values. A monitoring plan to identify conditions when blooms could potentially occur in each project reservoir would enable triggers for the initiation of monitoring events to be established, and avoid unnecessary monitoring. Provisions for updating the plan would enable the monitoring program to be modified to reflect new information about *Microcystis* as it becomes available, and conditions that could lead to monitoring prior to potential blooms refined.

If a monitoring program is implemented for *Microcystis* and its toxin in project reservoirs, monitoring results that trigger public health agency notification would enable such agencies to make a determination regarding whether there is a health risk to the public who come in contact with Klamath River water downstream of Iron Gate dam. Because algal blooms typically occur in reservoirs, not in free flowing river reaches, we expect the concentration of microcystin downstream of reservoirs where trigger levels may be detected, to be lower and less toxic. Consequently, we find that monitoring for *Microcystis* in free-flowing portions of the Klamath River from Iron Gate dam to the estuary, as Conservation Groups recommend, would be inappropriate to include as a condition of any new license that may be issued for this project. This would not preclude public health agencies from conducting such downstream monitoring if deemed necessary. Once detected, it may not be possible or feasible to remove *Microcystis* from project waters, as recommended by Siskiyou County. However, consideration of methods to reduce nutrient loading that create algal blooms and environmentally acceptable methods to control algal blooms when they occur, could be incorporated into the development of an overall water quality management plan, discussed in the following section.

Cladophora spp. is considered a nuisance algae capable of covering the entire stream bed. Schönborn (1996, as cited in Stocking and Bartholomew, 2004) found that *Cladophora* can displace all other aquatic macrophytes (individual aquatic plants large enough to be seen with the naked eye) due, in part, to a competitive advantage in nutrient enriched waters. This prolific, complex, and aggressive organism is considered an "ecosystem-reorganizer" capable of altering benthic food webs and centralizing the ecosystem by collecting fine organic matter and creating its own habitat (Schönborn 1996 as cited in

Stocking and Bartholomew, 2004). Stocking and Bartholomew (2004) link increases in *C. shasta* infections in juvenile salmonids with the spread of *Cladophora* in the Klamath River, as the upstream eutrophic reservoirs supply a steady flow of warm, nutrient-rich water to downstream river reaches. Stocking (2006, as cited by Resighini Rancheria, 2006) has shown that the primary habitat for the polychaete host for both *C. shasta* and *P. minibicornis* is sand with fine benthic organic matter and that the filamentous green algal *Cladophora* is a secondary habitat type. Polychaetes living on sand with fine benthic organic matter substrate are restricted to low-velocity areas, whereas polychaetes can exist in *Cladophora* in areas with higher water velocities (Stocking 2006, as cited by Resighini Rancheria). Furthermore, sand substrate is susceptible to scour and active bed movement in response to increased velocities, whereas attached algae such as *Cladophora* may be able to withstand higher velocities providing a relatively stable habitat for the intermediate polychaete host. Stocking (2006, as cited by Resighini Rancheria) sampled an extremely large and dense population of polychaetes at Tree of Heaven (around RM 170) in March 2005. When Stocking returned to sample again in July, after a high-flow event (discharge below Iron Gate Dam peaked at 5,380 cubic feet per second on May 18), much of the organic matter was gone and all polychaetes had disappeared (presumably both had been washed downstream). In contrast, polychaete populations in *Cladophora* beds remained intact. Eilers (2005) recorded decreased biomass of attached algae downstream of Iron Gate dam following a doubling of released flow (from about 600 cfs to about 1,300 cfs) a week prior to his field work.

FWS pathogen monitoring of juvenile salmonids in the Klamath River during spring of 2006 showed 10 incidences of *C. shasta* infection out of 391 (2.6 percent) samples taken through the second week of June (True, 2006).). Flows in spring of 2006 (up to 10,000 cfs) were substantially above median levels (as described in section 3.3.2.1, *Water Quantity*) suggesting that increased flows may be capable of moderating the infection rates in juvenile salmonids, possibly by displacing or disrupting the growth of either the attached algae or the ability of the host polychaete to exist within the *Cladophora* habitat. FWS pathogen monitoring in 2005 detected juvenile salmonid infection rates of up to 100 percent of both *C. shasta* and *P. minibicornis* (FWS memo undated. Accessed on the web, July 7, 2006, via: http://ncncr-isb.dfg.ca.gov/KFP/uploads/KR%20pathogen%20monitoring%20summary%2005-26-05.doc; last updated May 31, 2005). Reclamation classified 2005 as a "below average water year" (Reclamation, 2005c) where flows were well below the median during the time of recorded infections. Continued high nutrient levels in the Klamath River that create ideal colonization conditions for *Cladophora*, at sites with favored flow and substrate conditions, would enable the host polychaete to become reestablished, and *C. shasta* and *P. minibicornis* would likely continue to pose a serious threat to downstream salmon for the foreseeable future. However, by using information gathered during years when *C. shasta* infestations are low, such as 2006, it may be possible to develop methods to minimize future infestations by using controlled flows that displace either *Cladophora*, the hard substrate on which it grows, or the intermediate polychaete hosts that use this algae as its preferred habitat. We discuss the threat of *C. shasta* and *P. minibicornis* on anadromous fish and plans to control such threats in section 3.3.3.2.5, *Aquatic Resources-Disease Management* and the influence of flow on substrate conditions and active bed transport are discussed in section 3.3.1.2, *Geology and Soils*.

The presence of the blue-green algae *Aphanizomenon flos-aquae* in Upper Klamath Lake and its ability to fix nitrogen (convert inert nitrogen gas to more biologically available forms such as nitrite or nitrate) has been identified as a seasonally substantial source of nitrogen to Upper Klamath Lake (Walker, 2001; Oregon Environmental Quality, 2001). Dense blooms of *Aphanizomenon flos-aquae* occur in Copco and Iron Gate reservoirs during July and August (PacifiCorp, 2004a), and are a source of nitrogen into project waters and releases downstream.

A reservoir management plan that limits the amount of inorganic nitrogen inputs would reduce suitable conditions for *Cladophora* colonization and reduce the risk of *Microcystis* as these organisms thrive under nitrogen rich conditions. Because *Aphamizonmeon flos-aquae* algae fixes nitrogen, which increases the amount of available inorganic nitrogen and could enhance the proliferation of downstream

aquatic algae such as *Cladophora*, a reservoir management plan should address factors or conditions that support *Aphamizonmeon flos-aquae* blooms and identify measures that could be implemented to reduce such blooms in project reservoirs.

Project-wide Water Quality Management

As previously discussed, water quality within the Klamath River and throughout the mainstem portion of the project, is compromised for a number of water quality parameters which has triggered CWA 303(d) listings and the development of TMDLs, as well as other actions throughout the upper Klamath Basin. Numerous entities have filed comments that the project is a source of the poor water quality in the Klamath River and have filed recommendations designed to improve water quality to meet state standards.

Basin wide monitoring results show that Upper Klamath Lake is nutrient-rich, with hypereutrophic conditions observed during the summer. Project wide monitoring results show eutrophic conditions in all project reservoirs during the same time period. Project waters are typically high in total phosphorous and nitrogen, and experience extensive algae blooms during summer months resulting in high chlorophyll *a* concentrations. Upper Klamath Lake is undoubtedly responsible for a large portion of the nutrient loading downstream of Link River dam; however, there are additional inputs from the Lost River, Klamath Straits Drain, and other non-point sources downstream of Keno dam (e.g., runoff from agricultural lands along the downstream portion of the peaking reach and adjacent to J.C. Boyle, Copco and Iron Gate reservoirs). In addition, nutrient cycling in the project reservoirs (Kann and Asarian, 2005; Campbell, 1999) increases the complexity of readily using predictive modeling to accurately understand the nutrient regime within the Klamath River. PacifiCorp states that the project does not contribute to nutrient loading on a net annual basis, arguing that the reservoirs act to trap sediments and the nutrients associated with them, thus improving downstream water quality. Previous nutrient loading investigations by Campbell (1999) and Kann and Asarian (2005) suggest that the project reservoirs act as both sinks and sources depending on the seasonal conditions within the reservoirs. Regardless, nutrient availability contributes to algae blooms of *Aphanizomenon flos-aquae,* a nitrogen fixing algae, in all mainstem Klamath River reservoirs, and attached algae growth downstream of the project which, as discussed in the previous section, has other undesirable environmental effects.

PacifiCorp, as part of their water quality certification application, proposes to develop comprehensive reservoir management plans aimed at reducing algae concentrations, improving DO, and improving pH in J.C. Boyle, Copco, and Iron Gate reservoirs (letter from C. Scott, Project Manager, PacifiCorp, to the Commission, dated May 12, 2006). The plans would include evaluation of technologies and potential effects of implementing them on the conditions resulting from the high nutrient and organic inputs. The plans would also provide for evaluating the appropriateness of treating algal blooms with copper-based algaecide. In addition, the plans would include further evaluation of hypolimnetic aeration (as previously discussed in *Dissolved Oxygen Remediation*) and epilimnetic or surface aeration/circulation. PacifiCorp expects that actions identified in the plans would achieve the following: reduced hypolimnetic BOD and ammonia (through oxidation of these compounds), reduced orthophosphate (through retention in sediments), and a decrease in algae populations in surface waters that would lead to decreased fluctuations in pH.

The Forest Service recommends that PacifiCorp work cooperatively to address cumulative effects on water quantity and quality in the Klamath basin through appropriate remediation such that water influenced by the project is of sufficient quality to meet or exceed applicable state objectives. The Forest Service further recommends that PacifiCorp study the feasibility of improving Klamath River nutrient levels in and downstream of project reservoirs by mitigating nutrients released in project river reaches and reservoirs, including offsite remediation to improve nutrient loading from Upper Klamath Lake.

Oregon Fish & Wildlife recommends that within 1 year of license issuance, PacifiCorp develop a water quality resource management plan, in consultation with Oregon Fish & Wildlife, and other state, federal, and tribal resource agencies. The plan would be updated every 5 years, in consultation with the agencies. PacifiCorp would submit annual reports to the Commission and the agencies that would include the annual work plan for the upcoming year and a report with narrative and graphs demonstrating compliance with water quality requirements and standards for project reservoirs and reaches. The report would also include a summary of non-compliant events for the following parameters: water temperature, DO, TDG, pH, chlorophyll *a*, nutrients (including nitrogen and phosphorus), and toxic algae.

Oregon Fish & Wildlife and the Hoopa Valley Tribe recommend that PacifiCorp implement mitigation measures and conduct water quality monitoring pursuant to the water quality management and monitoring plan(s) approved by the Oregon Environmental Quality and the Water Board in connection with the water quality certificates.

Our Analysis

Our review of available water quality information indicates that the Klamath River experiences tremendous nutrient inputs from upstream of the project and elevated nutrient concentrations within project reservoirs and downstream of Iron Gate dam. Generally, mean nutrient concentrations are reduced in the riverine reaches as compared to project reservoirs. Upper Klamath Lake and the surrounding agricultural lands are undoubtedly the source of much of the nutrient load in project waters; however, due to complex nutrient cycling dynamics, project reservoirs act as both a sink and a source of nutrients depending on the time of year.

PacifiCorp suggests that Copco and Iron Gate reservoirs trap and remove nutrients from the Klamath River. Table 3-29 shows the concentrations of total phosphorous, orthophosphate phosphorus, and ammonia in the hypolimnion of Copco reservoir increase in the summer, which could be used to support such conclusions; however, the concentration data alone are not enough to irrefutably support PacifiCorp's position. A nutrient mass balance study conducted on behalf of the Karuk Tribe and summarized by the Water Board (2005) indicates that the reservoirs have periods in which they both trap and generate nutrients. Nutrient load estimates by Kann and Asarian (2005) indicate that Copco and Iron Gate reservoirs act as sinks for the nutrients phosphorous and nitrogen during April, May, parts of July and August and October, but both reservoirs can act as a nutrient source to the Klamath River below Iron Gate dam during most of June and September. Likely pathways for this increased load include internal sediment loading and nitrogen fixation by cyanobacteria such as *Aphanizomenon flos-aquae*, according to Kann and Asarian (2005). Nutrient loading analysis was not available for the period from November through March, which could include the period of reservoir turnover when nutrients within the hypolimnion could become either available for transport downstream or undergo aerobically induced chemical processes that result in the formation of insoluble precipitates, which could settle out rather than be passed downstream. After settling to the bottom, nutrients would be released from the precipitates under anaerobic conditions the following year, resulting in an internal cycling of nutrients. Due to the limited field data, the net fate of the nutrients is not entirely clear. Our review of available temperature profiles for Copco and Iron Gate reservoirs (figure 3-23) indicates that in 2002, fall turnover likely occurred between September and October at Copco reservoir. In 2001, fall turnover likely occurred between October and November at Iron Gate reservoir. The potential effect of nutrient releases from Iron Gate development associated fall turnover on downstream aquatic habitat is unknown. Spawning adult fall Chinook salmon would be in the river during this time frame. The Water Board is conducting a follow-up study that broadens the temporal and spatial data collection that limited the Kann and Asarian (2005) study.

Results from Kann and Asarian (2005) are supported by an earlier investigation by Campbell (1999) who also concluded that the project reservoirs act as both nutrient sinks and sources. Campbell concluded that there is a general increase in phosphorus loading longitudinally from Keno to below Iron

Gate dam which is not completely explained by increases in flow between the two sites and may be caused by internal nutrient cycling in the project reservoirs. Campbell further notes that although internal nutrient cycling in the project reservoirs was not quantified, the reservoirs in series do not seem to be functioning as a substantial nutrient sink between Keno and Iron Gate dam.

PacifiCorp acknowledges that Keno reservoir is seeded with algae passed from Link River, such that the same nutrient cycling dynamics occurring in Upper Klamath Lake also would be likely to occur in Keno and other downstream reservoirs. The total nitrogen balance developed for the Upper Klamath Lake TMDL indicates that Upper Klamath Lake is a seasonally important source of nitrogen (Kann and Walker, 2001). The primary source for this increase is internal nitrogen loading from nitrogen fixation by the blue-green alga *Aphanizomenon flos-aqaue* (Kann, 1998 as cited by Oregon Environmental Quality, 2002). The ongoing Water Board nutrient balance study for Copco and Iron Gate reservoir should provide resolution of this complex issue at these reservoirs. We conclude, based on our review of the available information that Copco and Iron Gate reservoirs act as sources of inorganic nitrogen during the summer, at least during relatively dry years primarily because the reservoirs create conditions that foster algal blooms of *Aphanizomenon flos-aqaue* and associated nitrogen fixation.

DO and pH in project-influenced waters are indirectly affected by nutrients because they are related to background water quality conditions, photosynthetic activity, and the amount of organic material exerting biological oxygen demand in the water. A shift in nutrient cycling in project reservoirs and outflow to inorganic nitrogen could act as a stimulant to enhance growth of attached algae in the Klamath River downstream of Iron Gate dam. Based on our review of available information, project reservoirs contribute to increased nutrient enrichment both within and downstream of project reservoirs on a seasonal basis, with associated related adverse affects (i.e., low DO during the summer and early fall and increased habitat for the *C. shasta* polychaete host, discussed in the previous subsection). Table 3-29 shows ammonia accumulates in the hypolimnion of both Copco and Iron Gate during the summer into October. Ammonia concentrations in the Klamath River above the confluence with the Shasta River were recorded at the highest levels in October, which is not unexpected under reduced conditions; however high levels in a well mixed environment such as the Klamath River at the confluence of the Shasta River (over 13 miles downstream of Iron Gate dam) suggests turnover at Copco and Iron Gate reservoirs or fish hatchery effluent could be responsible for the elevated ammonia concentrations. Ammonia can be toxic to fish. Therefore, we conclude that it is appropriate for PacifiCorp to assess measures to reduce such nutrient-related project effects, as PacifiCorp proposes and others recommend.

Development of reservoir management plans, as proposed by PacifiCorp, would address conditions stemming both directly and indirectly from the high levels of nutrients in project waters. Assessing a variety of technologies for reducing algae concentrations and enhancing the DO and pH of project waters would identify potentially effective measures to be implemented to address known water quality problems. However, development of separate management plans for each project reservoir would make it more difficult to take a comprehensive approach to addressing water quality issues, as previously discussed in *Keno Reservoir Water Quality Management*. We consider a more effective approach to water quality management to include all project-affected waters in a single comprehensive water quality resource management plan, as recommended by Oregon Fish & Wildlife. By including all project reservoirs and free-flowing reaches influenced by the project (e.g., project bypassed reaches, the peaking reach, and project-influenced portions of the Klamath River downstream of Iron Gate dam) in such a plan, water quality monitoring and potential remedial measures would incorporate inter-relations of reservoir dynamics with those of free-flowing project reaches into deliberations regarding measures that should be implemented.

We consider consultation with appropriate resource agencies in the development of any comprehensive water quality resources management plan to be essential. In some instances, potential measures for controlling water quality issues within project waters may entail balancing benefits against potential adverse effects. For example, using an algaecide to control a *Microcystis* bloom could be

effective in reducing the amount of microcystin toxin, and associated human health risk, in project reservoirs. However, depending on the algaecide used, there could be associated adverse water quality effects. In addition, as treated algae die and settle to the bottom of the reservoir, nutrients within the algal cells become susceptible for release and reintroduction to the water column at a later time. Resource agencies that represent the local natural resources and the related public health interests should be involved in such decisions.

Although we agree with the Forest Service that offsite measures to reduce nutrient loading coming into the project could help control nutrient levels within the project-influenced portion of the Klamath River, we consider it appropriate to consider such measures in plans that address loading to the Klamath River from throughout the entire basin. For example, we conclude the forthcoming TMDL and Reclamation's CIP would address loads entering the Klamath River and we consider it unreasonable to assign to PacifiCorp the responsibility of nutrient removal prior to reaching the project. However, provisions for periodic updates to a comprehensive water quality management plan specific to the Klamath Hydroelectric Project would enable parallel water quality enhancement initiatives to be incorporated into the plan, as appropriate. Although the outcome of PacifiCorp's proposed assessments of measures to control algae and related water quality problems associated with high nutrient and organic input may identify techniques that could be used directly in project waters, another possible outcome could be that it may be more effective to treat water before it is influenced by the project. Cooperation and coordination with other entities with an interest in addressing basin-wide water quality issues could lead to creative solutions to such issues. As discussed in *Keno Reservoir Water Quality Management*, assessing measures that would reduce the nutrient load of water passing from Keno dam, could effectively address project-related water quality issues at Copco and Iron Gate reservoirs. We discuss the basin-wide efforts targeting nutrients and other water quality analytes in section 3.3.2.3, *Cumulative Effects*.

Project operations contribute to water quality conditions that affect the taste and odor of project waters and could affect the flesh of harvestable salmonids and other aquatic resources that occur within the river. Table 3-34 indicates that two-thirds of recreational users in the project area had negative perceptions of the water quality, commenting on its color, turbidity, and odor. Given the eutrophic conditions within the reservoirs and the nutrient and organic matter loading to the river, it is not unreasonable to imagine the water would have a distinctive taste. We have no information regarding what specific conditions are causing taste and odor complaints by recreational users, but given the prevalence of algal blooms in project reservoirs, we suspect that such blooms are the likely cause of taste and odor problems. In addition to algal blooms, taste and odor issues at reservoirs are often associated with hydrogen sulfide, which produces a "rotten egg" taste and smell. Hydrogen sulfide production typically occurs as a byproduct of anaerobic decomposition of organic matter. Conditions that would allow hydrogen sulfide production (high organic matter and anoxic conditions) are present when Copco and Iron Gate stratify in the summer. We have no direct evidence that this is the case at any of the project reservoirs, but it would not be unexpected. Methane production, which is strongly suspected as occurring under certain similar anoxic conditions, at least in Iron Gate reservoir (Eilers and Eilers, 2004), can also produce taste and odor problems. Additional unpleasant odors could stem from the decomposition of algal mats that are attached to the shoreline providing a source of odors in areas visited by shoreline recreationists. A water quality management plan that includes measures that would reduce the likelihood of algae blooms, as well as enhance the DO of hypolimnetic water in Copco and Iron Gate reservoirs would also likely serve to reduce the taste and odor issues of project waters.

Dam Removal to Enhance Water Quality

Oregon Fish & Wildlife and the Hoopa Valley Tribe recommend that if it is not feasible to meet water quality objectives for water quality certification through modification of project facilities and operations, PacifiCorp should prepare a decommissioning amendment application for the subject facility,

in consultation with state, federal, and tribal stakeholders, in order to achieve compliance with applicable water quality objectives.

The Hoopa Valley Tribe states that "PacifiCorp's own analyses make it clear that the Klamath Hydro Project's effects on water temperature are immitigable; therefore, the only way to substantially reduce the impacts is to remove all KHP dams and drain the reservoirs." We consider this to be a recommendation for project dam removal to enhance the downstream water temperature regime for salmonids.

Conservation Groups recommend that PacifiCorp prepare a decommissioning plan in consultation with federal state, tribal, and other relicensing parties that results in the modification or removal of project facilities and operations to achieve compliance with all applicable water quality objectives.

Our Analysis

Both Oregon and California have listed project waters as "impaired" because they fail to meet applicable water quality objectives. We assess the potential effects on water quality resulting from removal of each mainstem dam because numerous parties have recommended the removal of some or all project dams. Many parties suggest that dam removal may be the only means to effectively address adverse project-related water quality effects. If project operation can be demonstrated to be responsible for continued violations of applicable water quality objectives after implementation of reasonable measures, and it is not feasible to correct the problem, we consider it appropriate to consider decommissioning the development. However, we expect considerable effort to be expended to identify all options to correct the problem before decommissioning is considered. If water quality objectives are not met for reasons that aren't related to project operations (e.g., the quality of water entering the development is similar to the quality of water leaving the development), it would be inappropriate to consider decommissioning the development. We do not expect the Fall Creek diversion dams to have any long-term effect on water quality. We do not consider removal of either diversion dam to be a reasonable option because applicable water quality objectives are currently being met. Therefore, we do not further discuss removal of these dams to achieve water quality objectives.

PacifiCorp's temperature modeling results show a Klamath River without hydroelectric dams would generally be warmer in the spring, more variable in the summer and fall (in particular, downstream of Iron Gate dam, as shown in figure 3-37), and similar to existing conditions between December and March. Unfortunately, because many of the other parameters in the model (e.g., pH, nutrients, and algae) are driven by much more complex biochemical processes than temperature,[43] modeling results for these parameters are contingent on the quality of the entire dataset and subject to variable interpretation. We base much of our analysis of the potential effects of dam removal on our review of existing water quality data from the riverine reaches and general principles that typically influence water quality. Without project dams and their associated reservoirs, the river would become well-oxygenated below the Keno dam site, due to mixing and reaeration afforded by natural river systems in steep, fast flowing environments. The Klamath River without project dams would still experience high levels of nutrients and organic matter originating from upstream sources, unless measures are implemented by other entities to reduce nutrient input. Given the high inputs to project waters, nutrients would continue to persist in project area waters in the absence of water treatment by other parties, and it is likely that without treatment of water entering the Klamath River from Link River and the Klamath Irrigation Project, Klamath River water quality would continue to be impaired. More importantly, conditions that support planktonic algae, including *Microcystis, Aphamizonmeon flos-aquae*, and other species that cause blooms in project reservoirs, would be diminished because such algae do not thrive in free-flowing reaches with

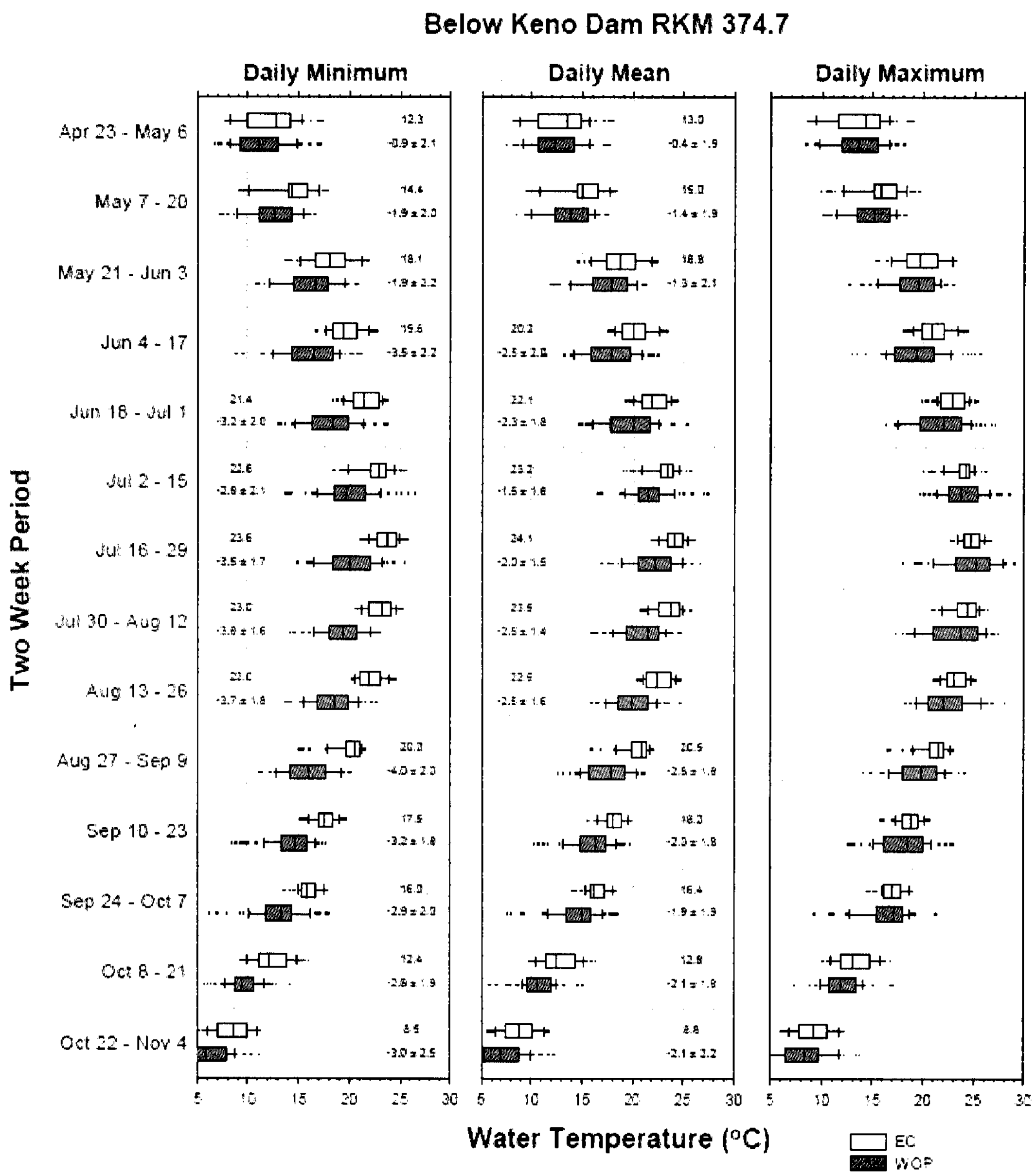
[43]Temperature is a physical process and as such is relatively simple to model, as the physics that affect it are well understood.

turbulent conditions, such as would exist in the Klamath River without project dams. Therefore, the geographical extent of Klamath River impairment would likely be reduced with mainstem project dam removal.

Removal of Keno dam would result in substantial changes to the thermal regime in the formerly impounded area, as the surface area would be substantially reduced and the residence time of water passing through the former reservoir site would be decreased, thus reducing solar warming of the impounded water. However, inflow to the Klamath River from irrigation runoff and from Upper Klamath Lake would still be warm. Figure 3-39 shows the expected temperatures below Keno dam under a "without project" scenario summarized by 2 week time periods. Daily maximums under the without project scenario would be similar to existing conditions; however, the greatest differences would be in the daily minimums, which could be almost 4°C lower than the existing conditions during the warmest periods in July. Similarly, daily average temperatures would be lower without the project, with temperatures about 2°C lower during the same time period. We discuss the effects of such temperature differences on salmonid refugia in section 3.3.3.2, *Aquatic Resources*.

High nutrient inputs would be expected to continue, but because the reach would be free flowing there would be a decrease in planktonic algae and a likely increase in attached algae (including *Cladophora spp*.) and submergent and emergent vegetation. Biggs (2000, as cited by Resighini Rancheria, 2006) reports that rivers around the world follow common patterns in response to localized nutrient enrichment. He states that, as long as additional nutrient inputs do not occur, nutrient concentrations typically diminish as the river flows downstream. Increased nutrient uptake by periphyton below a source is documented by USGS investigations on the South Fork Umpqua River in Oregon. USGS concluded that periphyton acts as an effective sink for nutrients entering the South Umpqua River (Tanner and Anderson, 1996). The free-flowing Oregon portion of the Klamath River below Keno dam is currently dominated by nuisance filamentous green algae species (i.e., *Cladophora*) (Oregon Environmental Quality, 2002), which would likely continue in the future. However, the distribution might shift depending on any future changes in the nutrient regime and whether or not any dams are removed.

The continued loading of organic material from Upper Klamath Lake and the shallow nature of the relatively low gradient of the Klamath River currently submerged by Keno reservoir (see figure 3-2) are conditions that would persist post-dam removal and may continue to exert an elevated biological oxygen demand throughout the water column. This may result in a continuation of DO conditions that are similar to current conditions in that the high biological demand would compromise DO concentrations resulting in low DO levels. Because the portion of the Klamath River now impounded by Keno dam would be returned to a shallow river, high nutrient inputs would stimulate aquatic plant growth, which would also contribute to fluctuations in DO concentrations (NAS, 2004). If Keno dam is removed, the former Lake Ewauna would not serve to retain fine-grained sediment and associated nutrients and other contaminants, because the bedrock sill that formed Lake Ewauna was removed when the original regulating dam was constructed at Keno (see section 3.3.1.1, *Geology and Soils*). This could allow for some turbulence causing reaeration; however given the shallow, meandering nature of the reach this may only result in modest aeration and may not overcome the biological oxygen demand. In general, we expect changes in nutrient and DO concentrations in the former Keno reservoir area and the downstream Keno reach, if Keno dam should be removed, to be related to a shift from free floating planktonic algae to attached algae and emergent vegetation which could begin the nutrient assimilation process closer to the source of inputs.



[a] Box plots (line inside box is median, box ends are 25th and 75th percentiles, whisker ends are 10th and 90th percentiles, dots are outliers) of daily minimum, mean, and maximum temperatures predicted by PacifiCorp's Klamath River Water Quality Model below Keno dam.

[b] Models estimate Existing Condition (EC) and Without Project (WOP). Numbers adjacent to the box plots are the mean temperature under EC (top) and the mean difference (WOP-EC) ± 1 SD (bottom).

Figure 3-39. Composite box plots[a] of two week summaries of modeled[b] water temperature from April to November for the years 2000 through 2004 below Keno dam. (Source: Resighini Rancheria, 2006)

The Keno reach upstream of J.C. Boyle reservoir is generally steep, free flowing, and has a boulder type substrate, and waters entering Boyle reservoir are well aerated. Residence time in J.C. Boyle reservoir is short compared to other reservoirs (about 3 days), which limits the amount of time for alteration of water quality directly related to the project. Little sediment has accumulated in the reservoir according to available information (see table 3-1). If J.C. Boyle dam would be removed, we expect there would be little effect on downstream water quality. The exception would be a substantial increase in water temperature in the J.C. Boyle bypassed reach because the increased volume of water would dilute the coldwater inflow from springs in this area. Similarly, the temperatures in what is now the peaking reach would be modified by eliminating the swings caused by peaking operations and the influence of the spring water in this reach during non-generation periods. However, we expect that daily averages would be similar to existing conditions. We discuss the loss of cold water salmonid refugia associated with this scenario in section 3.3.3.2, *Aquatic Resources*.

Removal of Copco No. 1 and Iron Gate dams would result in the greatest effects on Klamath River water quality due to loss of their associated reservoirs. Without these two dams, we expect the Klamath River would experience reduced ammonia and pH fluctuations, as these conditions are associated with algae blooms, anaerobic decomposition, and stratification processes within the reservoirs, as well as a reduced risk of *Microcystis* blooms. Removal of Copco No. 1 and Iron Gate dams would likely result in changes in the distribution of attached algae and moderate DO and pH. Without Copco and Iron Gate, temperatures below Iron Gate would experience more diurnal variability than existing conditions; however this variability would not be as extreme as without project scenario predictions (PacifiCorp, 2005).

Removal of Copco No. 2 dam would return flows to the Copco No. 2 bypassed reach providing natural aeration from the turbulent passage of water over the coarse, steep gradient in this reach, thus improving DO. However, because of the lack of a sizeable impoundment we do not expect additional effects on water quality.

With an abundance of nutrients in the water, aquatic plants thrive in the Klamath River and the mainstem reservoirs (Campbell, 1999). Without Iron Gate and Copco No. 1 dams in place, planktonic algae densities would substantially decrease, allowing opportunistic attached algae and rooted vegetation to capitalize on the nutrient-rich waters within the river in areas with suitable substrate. The dense algae blooms that currently occur in Copco and Iron Gate in July and August are dominated by the same nitrogen fixing algae that contributes to increased nitrogen in Upper Klamath Lake. Removal of the dams would reduce the seasonal nitrogen loading potential by the algae, thereby reducing nitrogen availability within the area or downstream. The greatest amount of nutrient uptake by attached algae or rooted vegetation would most likely occur close to the source of nutrient inputs, which without Copco or Iron Gate would be closer to Keno reservoir and nutrient uptake would continue through the project area and beyond.

Should *Cladophora* become established in formerly impounded river reaches at Copco and Iron Gate, as figure 3-34 suggests could occur, we expect it to thrive, given the high nutrient concentrations entering the river from the upper basin. This could have implications for anadromous fish restoration, discussed in section 3.3.3.2.3, *Anadromous Fish Restoration*. However, the nutrient dynamics in the Klamath River would be altered if one or more mainstem dams were to be removed, and predicting future nutrient conditions and associated *Cladophora* colonization in the vicinity of the current Copco and Iron Gate dam sites would be difficult. Because the river would be free flowing for a longer portion of the reach, there would be ample opportunity for waters to be well-aerated from natural turbulence, dampening the current extremes in DO concentrations in the middle section of what is now Copco and Iron Gate reservoirs. When oxygen is present, phosphate typically is bound to sediment particulates, becoming unavailable for plant growth.

Hazardous Substances

The Bureau of Land Management specifies that PacifiCorp file a hazardous substances plan for oil and hazardous substance storage, spill prevention, and clean up with the Commission prior to planning, construction, or maintenance that may affect Bureau of Land Management-managed land. At least 90 days prior to filing the plan with the Commission, PacifiCorp would submit the plan to the Bureau of Land Management for review and approval. The plan would outline procedures for reporting and responding to releases of hazardous substances and make provisions for maintaining emergency response and HAZMAT cleanup equipment sufficient to contain any spill from the project.

The Bureau of Land Management also specifies that PacifiCorp should semi-annually provide the Bureau of Land Management with information on the location of spill cleanup equipment on Bureau of Land Management-managed land and the location, type, and quantity of oil and hazardous substances stored in the project area. PacifiCorp would inform the Bureau of Land Management immediately as to the nature, time, date, location, and action taken for any spill affecting Bureau of Land Management-managed land.

PacifiCorp submitted alternative 4(e) conditions to the Bureau of Land Management (filed with the Commission on April 28, 2006). PacifiCorp's alternative 4(e) condition modifies the Bureau of Land Management condition by stating that it would implement and maintain spill prevention control and countermeasure plans at all project facilities in compliance with 40 CFR Part 112. PacifiCorp states that the plans would be made available to the Commission and the Bureau of Land Management as requested. Finally, PacifiCorp states that the scope of this condition would only include Bureau of Land Management lands within the project boundary.

PacifiCorp also provided an alternative 4(e) condition to semi-annually provide the Bureau of Land Management with information on the location of spill cleanup equipment on Bureau-managed land and the location, type, and quantity of oil and hazardous substances stored in the project area. PacifiCorp states that it would maintain spill clean-up equipment on Bureau of Land Management lands within the project boundary in accordance with the required spill prevention and cleanup plans. PacifiCorp proposes to submit annually a copy of its annual emergency and hazardous chemical inventory (Tier II form) to the appropriate state jurisdictional agencies in accordance with federal regulations. PacifiCorp does not say that it would provide this Tier II form to the Bureau of Land Management. It agrees to notify the Bureau of Land Management of any spills on Bureau lands within the project boundary, but does not provide for notification if spills affect, but do not occur on, Bureau lands.

Our Analysis

In accordance with 40 CFR §112.1 of EPA's regulations, a hazardous substance plan (also referred to as a spill prevention control and countermeasure plan) is required to be in place for any facility where unburied storage capacity exceeds 1,320 gallons of oil or a single container has capacity in excess of 660 gallons. In addition to the onsite storage of lubricants and other oil products, transformers at the J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate powerhouses are oil-cooled and would be of sufficient capacity to exceed the threshold to require a hazardous substances plan to be in place, independent of this relicensing procedure. This plan would provide a quick reference to procedures and notifications in case of oil spills and reduce the possibility of oil or other hazardous substances reaching the Klamath River if a spill occurs. A hazardous substances plan would minimize the amount of petroleum products that would enter project waters in the unlikely event of a spill. There is no evidence that PacifiCorp stores smaller quantities of oil than those that would trigger preparation of a hazardous substances plan or additional hazardous substances besides petroleum products within the existing or proposed project boundary. However, if such is the case, extending the hazardous substances plan to include smaller quantities of oil and other hazardous substances would reduce the risk of contamination of project lands and waters by these products and would reduce the extent of contamination should a spill

occur. If hazardous substances not covered under PacifiCorp's existing hazardous substances plan should be needed prior to any planned construction or maintenance activities, we consider inclusion of a site specific addendum to PacifiCorp's existing plan to cover this construction or maintenance activity to be reasonable and consistent with documented Best Management Practices. For construction or modifications of existing project facilities, the site-specific hazardous substances plan addendum, with the base plan, could be submitted for approval as part of the final plan for the site.

We are not aware of any actions proposed by PacifiCorp as part of this relicensing proceeding that would entail new construction or maintenance that would not be addressed in a plan proposed by PacifiCorp or recommended by the staff. The type of construction or maintenance that would require a new plan for oil and hazardous substances storage and spill prevention and cleanup would typically require a licensee to file a request for a license amendment with the Commission. The need for such a new plan would be addressed in the license amendment proceeding.

PacifiCorp already reports information on the location of spill cleanup equipment and the location, type, and quantity of oil and hazardous substances stored in the project area to the appropriate state agencies on an annual basis. This report includes Bureau of Land Management managed lands within the project boundary. The Bureau of Land Management has not made its case why the existing annual reporting should be shortened to semi-annual reporting and why the existing reports provided to state agencies are not sufficient to document on-site hazardous material inventories. Coordinated efforts between the Bureau of Land Management and the state agencies would alleviate the need for PacifiCorp to prepare duplicative inventory and reporting information as specified by the Bureau of Land Management. Providing copies of the reports that PacifiCorp provides to state agencies to the Bureau of Land Management should not be burdensome and would keep the Bureau of Land Management informed regarding the location of project-related hazardous material storage sites and spill clean-up equipment.

3.3.2.3 Cumulative Effects

Construction of the project dams resulted in areas of the river where the physical processes that control water quality have experienced a shift, as the processes in lakes are markedly different relative to the river environment. Although at times water quality meets applicable state water quality objectives (typically during the winter, high flow months) the water quality within some of the project impoundments (i.e., Keno, Copco, and Iron Gate reservoirs) has evolved to mimic highly productive lakes, which experience algal blooms and complex nutrient cycling and loading processes. Diversion of water for hydroelectric generation has substantially altered flow and temperature regimes in the bypassed reaches; however, under the existing hypereutrophic conditions, diversion of water from the J.C. Boyle bypassed reach has resulted in an improvement to that reach's water quality. Other actions throughout the upper Klamath River Basin that could cumulatively affect water quality include management plans and policies, land use practices, and changes in agricultural market conditions. We discuss below the potential effects of other activities not directly under the Commission's control that have a bearing on project water quantity and quality.

Implementation of the TMDL for Upper Klamath Lake and the subsequent reduction in phosphorous loading to the lake should, over time, improve water quality within the lake and in releases to the Link River, in addition to releases to the Klamath Irrigation Project through the A canal. Development of the TMDL for the Klamath River would build on the existing TMDL for Upper Klamath Lake and allocate acceptable nutrient loads to the Klamath River from point and non-point sources throughout the Upper Klamath Basin. Once loads have been established, NPDES permit holders and agricultural land owners would become eligible to apply for funding to implement measures to reduce the nutrient loads leaving their properties and entering the Klamath River. This program would provide benefits to water quality throughout the Klamath River over the anticipated term of a new license. The TMDL program relies on voluntary involvement for loads identified from non-point sources; therefore, nutrient load reductions to the allocated size may not be fully realized as farmers and ranchers choose

between converting portions of their land to best management practices or maximizing their property's agricultural potential.

Reclamation's CIP would work to bring agencies and non-governmental organizations interested in protecting water quality and other affected resources together to develop policies and plans to alleviate the current stresses on water quality and aquatic resources. Currently the CIP is in its third draft and provides a framework of interagency collaboration to aid existing ecosystem restoration and water management efforts developed at the local level to advance more rapidly by providing resources, coordination, and communication. The CIP can also fund research to increase understanding of the Klamath River system and monitoring to evaluate progress toward program goals. Implementation of a final CIP would provide the framework to coordinate basin-wide restoration and monitoring efforts in a collective effort to improve water quality and other resources.

Reclamation must maintain certain lake elevations and river flows through implementation of the conditions specified in Biological Opinions issued by FWS and NMFS. At the same time, Reclamation must operate the Klamath Irrigation Project, which includes water in Upper Klamath Lake and releases to the Link River and A canal, consistent with its tribal trust obligations, contracts for the delivery of water throughout the Klamath Irrigation Project, and water supply to the Lower Klamath and Tule Lake National Wildlife refuges. As such, water availability for other purposes (e.g., flushing flows, additional spillage, etc) is limited and during dry years becomes a highly contested resource. Over time, the overall limitations on water availability and dynamic hydrographs contribute to conditions that result in a channel that becomes stable and prone to other undesirable consequences to water quality and aquatic resources. The ability to store additional water at Long Lake is currently under study as a means to increase water availability throughout the Klamath River Basin.

Inflow to the Klamath Hydroelectric Project is largely the result of releases from Link River dam and withdrawals or return flows from the Klamath Irrigation Project. The limited active storage of the project reservoirs greatly limits the effects of project operations during flooding events or extremely dry periods along the middle and lower reaches of the Klamath River. Maintenance of the current water level regime within Keno reservoir would ensure the continued supply of water to and from the Klamath Irrigation Project. We discuss cumulative water quantity effects on aquatic and riparian habitat in section 3.3.1.3, *Geology and Soils*; and effects on aquatic biota in section 3.3.3.3, *Aquatic Resources*, and 3.3.5.3 *Threatened and Endangered Species*.

Water demands in other tributary watersheds to the Klamath River can put an additional strain on the resources that rely on the Klamath River. The California State Water Project controls releases from the Trinity River to the Klamath through diversions to the Central Valley, which, depending on the water year type, can have a substantial effect on flows in the lower Klamath River. Diversions of water result in reduced volume entering the Klamath River, exacerbating high temperatures, especially during low flow years, and further stressing anadromous fish. The headwaters of the Trinity are largely undeveloped resulting in good water quality that, before the California State Water Project, would help dilute the naturally high nutrient loads within the Klamath River and buffer temperature extremes. Demand for these tributary sources limits the ability of the natural system to provide protection to the resources that rely on it. Collaboration between interbasin water users (including transfers from the Klamath Basin to the Rogue River Basin to the north and the California State Water Project to the southeast) and diverters could lead to more effective management of flow releases to the Klamath River, which could provide relief from extreme temperatures. In addition, during non-dry years, collaboration may provide flushing type flows to mobilize the substrate which could reduce attached algae distribution and may lower *C. shasta* infection rates among salmonids within the lower Klamath River.

The expiration of the 1956 contract between PacifiCorp and Reclamation which provided reduced electrical rates to Klamath Irrigation Project irrigators may result in changes in agricultural practices that change the amount of Klamath River water that is used for irrigation. Because much of the water initially

used for irrigation is returned to the Klamath River, any reduction in irrigation water use would reduce the amount of nutrients and other agricultural byproducts entering the Klamath River during the summer growing season. Allowing fair market practices to determine resource allocation could lead to distribution patterns throughout the basin that could improve water quality as water users choose not to irrigate, change crops, or reduce farming efforts. On the other hand, a change to less expensive, less efficient irrigation practices (such as flood irrigation) may result in increased diversions which may reduce the quantity of water that is returned to the Klamath River

Extensive timber harvesting and conversion of land for resource extraction purposes (e.g., mining for gravel, gold, and other materials) throughout the watershed results in increased sediment and nutrient loads to the Klamath River. Increased sediment loading degrades water quality by increasing bedload and suspended solids in the water. As the solids settle, they create a shallower river channel susceptible to warming during months with the most daylight. During high flow events, previously settled sediments could become re-suspended, generating a deeper channel that would buffer the river from daily temperature swings. If the above-mentioned land types become reforested, the area would experience less direct runoff, increased potential groundwater contributions, and reduced pollutants. Effects would be dynamic and ongoing as land uses throughout the basin change due to numerous socioeconomic factors.

3.3.2.4 Unavoidable Adverse Effects

The project, as proposed, would continue to affect temperatures in the Klamath River. Implementation of strategic operations or facility modifications that use cool water stored in project reservoirs, as discussed previously, could temporarily alleviate project effects on temperatures downstream of Iron Gate dam; however these effects would be limited to a few degrees Celsius and last from a few days to at most a couple of weeks. In addition, even with implementation of best management practices that may be developed as part of a project-wide water quality management plan, it is likely that algal blooms would continue to occur in project reservoirs, albeit at a smaller scale and less frequently, and some degree of project-related nutrient enrichment would occur in the Klamath River downstream of Iron Gate dam.

Removal of any project dam(s) as recommended by various stakeholders would expose sediment previously trapped behind project reservoirs to scour, increasing the turbidity of the water downstream of any dam that might be removed. The magnitude and duration of this effect would be related to the amount of sediment trapped behind the dam (see section 3.3.1, *Geology and Soils*), which dam(s) are removed, the removal methods, and any actions taken prior to breaching the dam (e.g., dredging). Based on these factors, we expect the adverse effects from increased turbidity during and following dam removal to range from relatively short-term, minimal increases in turbidity, to increases in turbidity that could last for several years. If sediments should be contaminated, any release of such contaminants during dam removal could also adversely affect water quality.